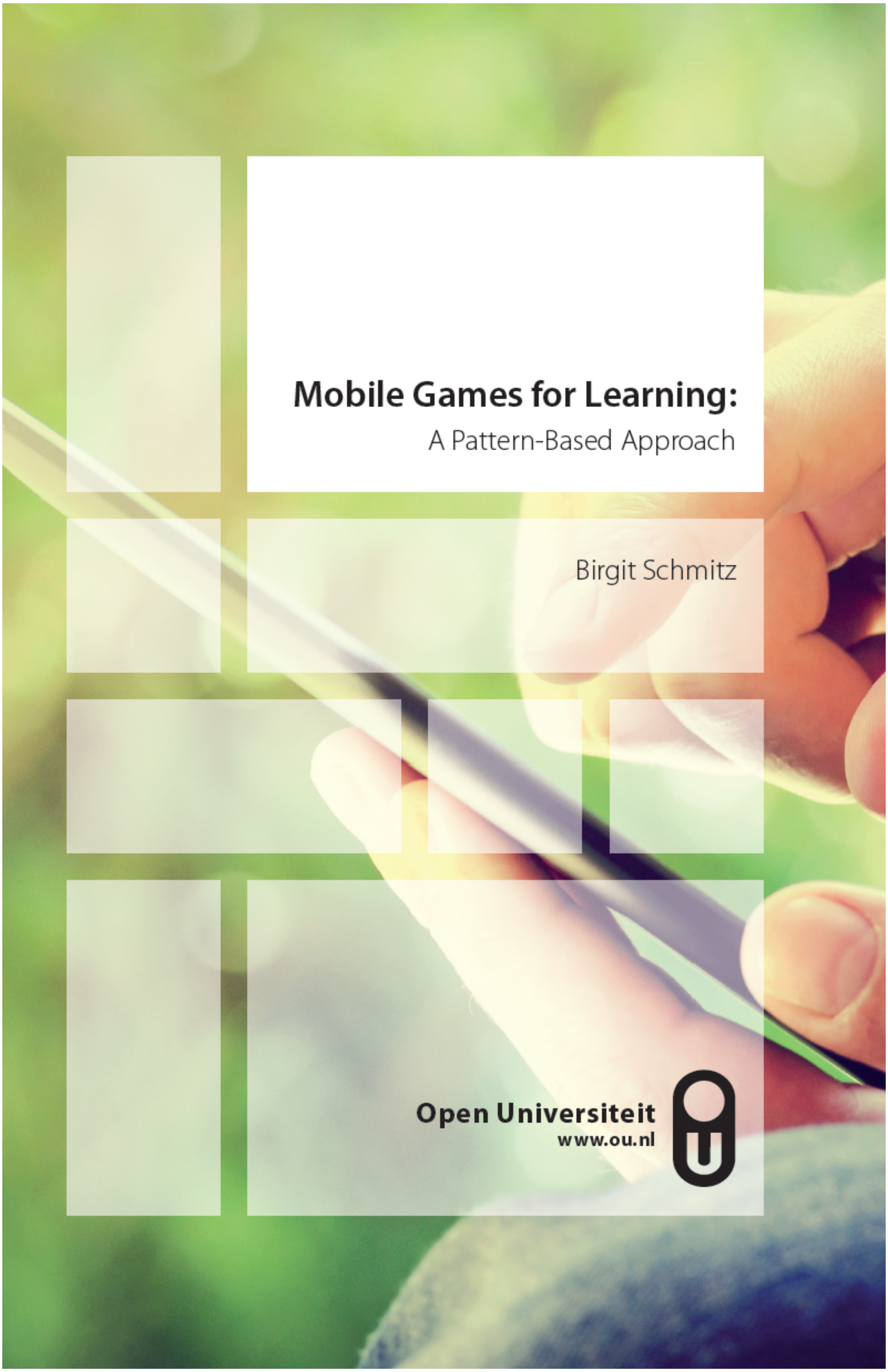
Mobile Games for Learning


Mobile Games for Learning:
A Pattern-Based Approach
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A Pattern-Based Approach

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General Introduction

> *Today's students have not just changed incrementally from those of the past, nor simply changed their slang, clothes, body adornments, or styles, as has happened between generations previously. A really big discontinuity has taken place. One might even call it a "singularity" - an event, which changes things so fundamentally that there is absolutely no going back. This so-called "singularity" is the arrival and rapid dissemination of digital technology in the last decades of the 20th century.*
>
> Marc Prensky (2001)

Today, pupils at the age of 15 have spent their entire life surrounded by and interacting with diverse forms of computers. It is a routine part of their day-to-day life and by now computer-literacy is common at very early age. Over the past five years, technology for teens has become predominantly mobile and ubiquitous within every aspect of their lives. To them, being online is an implicitness. Studies by the Pew Research Centre illustrate this. In the United States, 100% of youth aged between 12-17 years possess a mobile device and 37% of them own a smartphone. About 74% use the Internet mobile via cell phones or tablets and 25% are "cell-mostly" Internet users. They download apps, video chat, record and upload videos, they surf information on the Web, have functional skills of social networking and they play. A total of 97% of U.S. youth aged between 12-17 years play video games and 48% use a cell phone to do so (Lenhart, 2009; Madden et al., 2013). The possession of mobile devices is regardless of social or educational circumstances (Feierabend et al., 2010; Lenhart, 2009) and with their significant computing power, possessing a state-of-the-art mobile device can be put on a level with being equipped with a computer that enables access to information and education, anywhere and at any time (Johnson et al., 2011).

Meanwhile, more and more young learners bring their devices into the classroom and pupils increasingly demand for innovative and motivating learning scenarios that strongly respond to their habits of using media. With this development, a shift of paradigm is slowly under way with regard to the use of mobile technology in education. It has led to a plethora of innovative concepts and offers for teaching and learning, which, amongst others, acknowledges that the basic understanding and usage of technology young learners have, can be effectively harnessed for engagement inside the classroom (Gurung and Rutledge, 2014). However, simply using technology does not motivate learners who have lived in the midst of technology all their lives (Kiili, 2005; Wu et al., 2012). Only in combination with methodologically sound concepts can the use of technologies provide fertile ground for contemporary and purposeful, interactive learning environments.

The strive to better understand the determining factors of successful digital learning environments has been the request within the research field of Technology-enhanced learning (TEL) for the past 30 years. By now, a large body of literature exists, that reports concepts, use-cases and practical studies for effectively using technology in education. Within this field, a steadily growing body of research has developed that especially examines the use of digital games as instructional strategy. It stresses their potential as tool to assist student learning and most prominent as motor for engagement. Study results have shown that digital game-based learning "can be helpful to the academic achievements of players in addition to enhancing their social problem solving ability" (Kim et al., 2009), just as well as it can promote exploratory learning by rewarding players for their curiosity and support new discoveries and learning opportunities (Tüzün et al., 2009). Games are often effective because learning can take place within a context that is meaningful to the game and that is safe, e.g. virtual environments that simulate reality and enable risk taking without real consequences (Susi et al., 2007).

Activities for learning, which are embedded in meaningful contexts, can be used to increase intrinsic motivation, even if they involve abstract operations (Cordova and Lepper, 1996). While there exists a growing interest for pedagogical games in the research community, the topic still is controversial and educational practitioners often refuse to use it. The reasons are diverse and many argue with tight time schedules that do not allow for the search and integration of digital game-based learning offers into their pedagogical work. Also, successful professional development that includes teacher efficacy in using appropriate software is frequently missing (Kebritchi, 2010; Ketelhut and Schifter, 2011; Williamson, 2009) and last but not least, the acknowledged effects and potentials of using technology are not consistently communicated. In order to integrate technologies into school instruction and learning, "arguments are required that move beyond the simple enhancement and augmentation of learning and teaching by mobile media" (Cook et al., 2011, p. 182). Thus, for many this issue remains diffuse and is associated with extra workload and unclear learning results. But still, studies indicate that the interest in using digital games for learning is high and most teachers acknowledge and even value the assumed motivational potential such games have for learning (Ketelhut and Schifter, 2011). For educating learners at-risk, for example, who are increasingly difficult to reach by traditional education and training, game-based learning approaches can provide a chance to bring them back into education. (Douch et al., 2010; Feierabend et al., 2010; Lenhart, 2009).

Besides, the highly complex technologies and the many different gaming opportunities available make it increasingly difficult for educational practitioners to decide which game to choose for learning. Thus, several approaches have come into existence that try to define a common structure and language of games to better understand the complex issue (Björk and Holopainen, 2004; Cook, 2010; Kelle et al., 2011; Kiili and Ketamo, 2007; Maciuszek and Martens, 2010). Though these approaches are relevant to educational games, they do not specifically target the analysis of possible interrelations between individual game elements and pedagogical outcomes, a key factor for using games in an educational context. However, recent research has started to argue along these lines and to propose models for more specific game assessment (Arnab et al., 2014).

Sharples and Specht (2013) reason that regarding the use of technology in education, "a push-through from theory-informed research to innovative projects and then to widespread transformation of practice seems to be difficult because of the gap between the apparent enthusiasm of researchers and policy makers regarding the potential of technology and the attendant practicalities of selecting and implementing them in classroom settings". This applies to the use of educational games just as well. Despite the growing body of research in the field, remarkably little research exists that directly addresses educational practitioners (Ketelhut and Schifter, 2011) or offers practical methodologies and tools to guide the design process and to provide minimal guarantee in that the use of gaming principles is relevant for learning (Mariais et al., 2011).

The three parts of this thesis illuminate this gap and at the same time they represent a first approach in bridging it. Against the background of the ubiquitous influence of mobile technologies, pictured at the outset of this thesis, they rivet on mobile games for learning in the sense of "embedded, downloaded, or networked games conducted in handheld devices" (Jeong and Kim, 2008, p. 290), as they are a strong component of future scenarios for teaching and learning (Johnson et al., 2011). Thus, the main objectives of this research are:

Identifying how mobile games for learning can be designed to deliver new and engaging forms for teaching and learning.

Supporting the effective use and integration of mobile games for learning into educational practice.

Outline of the thesis

The first part of this thesis comprises Chapter 1 and 2 and outlines the theoretical approach. It proposes a framework to support the analysis and assessment of mobile games for learning. The framework lays foundation for the conceptualization of mobile game environments, which is subsequently introduced and evaluated in part two of this thesis. The game environments take into consideration different target groups, subjects and theoretical perspectives on learning. Along the process of their development we evaluate individual game patterns and finally analyze the impact of using them with regard to particular learning outcomes, which constitutes part three of this thesis.

This thesis draws on patterns as a recognized form for recording, calibrating and collaboratively refining expert knowledge that is flexible enough to address a broad spectrum of practices (Mor and Winters, 2007). In line with the original approach to patterns, which the architect Christopher Alexander et al. (1977) intended, it regards a pattern as a rule, which expresses the relationship between a certain context, a problem and a given solution. Based on this definition, a pattern does not only describe a certain form, but also the underlying design guidelines that define how to establish, realise and use a certain form. That is the reason why, within a particular context, a pattern can occur again and again without being realized identically at any time. The pattern approach has increasingly been applied to other areas such as the domain of educational science by way of pedagogical patterns (Kohls and Wedekind, 2011), for example, or to the design of digital games.

Chapter 1 starts with introducing the classification framework. It is based on a literature review of current research in the field from which evidence was abstracted for possible relationships between game design elements and pedagogical aims. To describe this relationship, the framework employs the established approaches of Game Design Patterns for Mobile Games (Davidsson et al., 2004) and categorizes them according to Bloom's taxonomy of educational objectives (Bloom, 1956). This way it supports the pedagogical understanding that different types of learning require different teaching methods to achieve them, i.e. learning behavior through imitation, learning processes through explanation and practice or learning creativity through playing (Prensky, 2007; Verpoorten et al., 2007; Derntl et al., 2009). Applied to the context of game based learning this implies that different types of learning require different games, e.g. inquiry learning can be supported by computer simulations (de Jong, 1991). Along these lines, different types of learning outcomes require different patterns. The current framework focuses on affective and cognitive learning outcomes. It presents a set of patterns, which were identified in the literature and which positively influence these two aspects. Results support the general assumption that mobile learning games have potential to enhance motivation and reveals that game patterns such as *Collaborative Actions, Augmented Reality, Pervasive Games* or *Physical Navigation* provide incentive to get engaged with a particular subject or a given learning content.

This review is further extended in **Chapter 2**. Based on the results from the previous review, this chapter more closely looks at the educational potential of pervasive games for learning. It has a particular focus on the patterns *Augmented Reality* and *Pervasive Games* and relates them to contextual attributes such as location, time or activity, which are introduced as an additional characteristic feature of the mobile game design patterns. From the review of practical papers it is gathered that pervasive games for learning can produce both affective and cognitive learning outcomes. Exemplary concepts are provided that illustrate the framework's support in evaluating how game design and learning intertwine. As a result it showed that mobile augmented reality (AR) gaming can be helpful to motivate and engage learners and can lead to improved attitude towards the learning materials. It provides potential to explore new learning and teaching environments, engages in critical thinking and enhances recall of materials and transfer of knowledge.

The review outcomes informed the conceptual approach of two mobile game environments that make up the second part of this thesis. Several formative studies guided their design and development from different perspectives. **Chapter 3** starts with framing the game development of *WeBuild*, which was designed in order to engage and motivate learners who are at-risk from dropping out of school. Building on a target group analysis and an exploration of the literature on how to create learning tools for this particular target group, Chapter 3 illustrates the pedagogical framework. It outlines the didactical premises, details the technical infrastructure and describes the game concept that is based upon the patterns *Physical Navigation*, *Team Play*, *Competition* and *Augmented Reality*. Results from formative assessment are directed at usability and motivational aspects of the game design. Testing the game in a training facility of the building industry indicated that learners accepted the game for the low entry barriers and were motivated to use the game in an educational context.

Another exemplary mobile game environment is presented in **Chapter 4**. It chronicles the development and implementation of *HeartRun*, a cardiopulmonary resuscitation (CPR) training approach for school children. *HeartRun* involves different roles and locations to simulate an unexpected emergency. In order to realize authentic activities that comprise the different roles, game tasks, locations and physical objects involved in an emergency, it employs the patterns *Roleplaying*, *Physical Navigation* and *Collaborative Actions*. The chapter aims at better understanding how such design decisions impact affective and cognitive learning outcomes. A series of studies were carried out that were guided by the principles and attributes of design-based research. The chapter illustrates how the game has evolved from its initial conception through an iterative process of (re-)designing and testing. It presents the results and discusses possible implications for design decisions, which surfaced from the studies.

Based on the results of the formative studies, mobile game environments were set up to conduct empirical studies. **Chapter 5** presents the outcomes of an experimental study to assess the impact of a mobile game environment on engagement and learning for learners at-risk. The mobile game is an instantiation of the game design pattern *Coupled Games* and is realized by coupling a PC Browser Game to a mobile game by way of SMS interventions. The chapter provides a detailed description of the instructional approach, the technical infrastructure, and the results, which are discussed subsequently with regard to learners' attraction to the game environment, their motivation to deal with learning content and their knowledge gain. The findings through seven-week gaming indicate that this pattern has potential to increase learners interest in a topic and can support learning activities for the target group.

The second empirical study is presented in **Chapter 6**. It was designed to investigate the impact of the location-based, collaborative roleplaying game *HeartRun* on behavioral outcomes. In order to realize the features frequently associated with mobile games, i.e. cooperative action between team players who have different tasks or roles and time-critical orientation in physical space, the study is rested upon the use of the patterns *Physical Navigation*, *Collaborative Actions* and *Roleplaying*. The experimental setting contrasted this approach to a more content delivery oriented version of the game without the mentioned patterns. A post-test control group with random assignment was used to assess the outcomes with regard to a series of behavior related concepts as well as CPR knowledge and competence. Results show evidence that pupils who participated in the location-based, collaborative roleplaying game held stronger beliefs in their capacity to provide CPR in case of emergency and also they held stronger beliefs in their actual helping in case of emergency.

The thesis concludes with a **General Discussion** on both the reported results from the formative studies and the experimental studies. From this, several design issues surfaced regarding the use of mobile games for learning within different educational settings, for diverse target groups and varying subjects. The concluding chapter summarizes these findings and, with regard to mobile game design patterns, discusses them with the intention to facilitate a better understanding of choosing and using mobile games for learning.

Part I

Theoretical Approach

Chapter 1

Effects of mobile gaming patterns on learning outcomes: a literature review

This first chapter introduces the classification framework that was set up to support design decisions in the field of mobile games for learning. The focus that guided the framework was the general understanding that the type of learning outcome an educationalist selects should direct the choice of teaching method. The different teaching methods are reflected by the different game design patterns. The framework matches them against possible cognitive and affective learning outcomes, which we have abstracted from reported research on mobile games for learning. Applying the framework to mobile learning games helps describing and sharing them.

This chapter is based on: Schmitz, B., Klemke, R., and Specht, M. (2012b). Effects of mobile gaming patterns on learning outcomes: a literature review, *International Journal of Technology Enhanced Learning*, 4(5-6), 345-358.

1.1 Introduction

Within the past five years, the number of mobile learning games (MLGs) has snowballed. For commercial and for scientific use they have been developed for various target groups and learning contexts (Lilly and Warnes, 2009) such as role-based history learning (Akkerman et al., 2009), interactively discovering the principles of digital economy (Markovic et al., 2007) or geometry (Wijers et al., 2010). Mobile learning games are considered to have potential for encouraging both cognitive and socio-affective learning in young adults (Mitchell, 2007). Also, Klopfer (2008) argues that mobile learning games enable situative learning offers that make a meaningful and valuable contribution to the process of learning by providing aspects such as temporal flexibility, natural communication or situated learning scenarios. The highly complex technologies and the many different gaming opportunities available make it increasingly difficult for educational practitioners to decide which game to choose for learning. Re-using and sharing a game is difficult without a clear and detailed description of the benefits, targeted learning outcomes and potential impact. There have been several efforts to find a common structure and language of games to better understand the complex issue (Björk and Holopainen, 2004; Cook, 2010; Kelle et al., 2011; Kiili and Ketamo, 2007). Still, there is a lack of scientifically acceptable methodology to evaluate mobile learning games. Therefore, the purpose of this chapter is to define a classification framework that helps to evaluate and to categorize mobile learning games and to identify mechanisms that support design decisions of future mobile learning games.

Methodologically, this chapter scrutinizes evaluation reports on mobile learning games (MLG). Based on the description of Game Design Patterns for Mobile Games by Davidsson et al. (2004) it identifies game design patterns and analyses how they might contribute to a particular learning outcome. Thereto, the patterns will be lined up against Bloom's taxonomy of educational objects (1956) within the affective and cognitive domain (see Figure 1.1). The framework might help to better understand the mechanisms of mobile learning games and to make use of the various effects they enable. Thus, it raises three questions:

Q1: How does a pattern influence learners' motivation to deal with a particular subject or a given learning content?

Q2: What are effective mobile game design patterns to support the acquisition of knowledge?

Q3: What are best practices for mobile learning games to support knowledge gain?

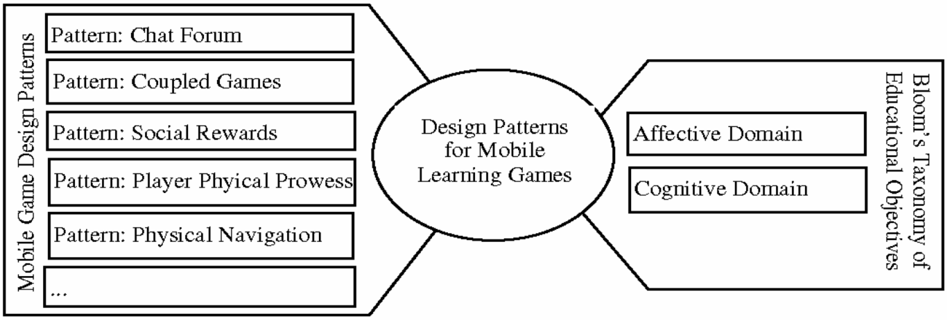

Figure 1.1 Framework for the analysis

1.2 Analyzing Mobile Learning Games

There are a number of mobile game-based learning projects that have already tested and evaluated the effects of mobile games on students' learning. Only few trace their findings back to individual game mechanisms or patterns in order to better understand why a game is successful. Instead, reports often reason effects with the use of the game itself, e.g. "students found the use of Lecture Quiz engaging, they perceived they learn more using such games" (Wang et al., 2008). While such statements are vital in that they back up the more self-evident use of mobile devices for learning, they allow no conclusions as to why and how this effect is transferrable and reproducible. In addition, no information is deducible about what gameplay elements influence learning outcomes. Studies often lack empirical evidence on the motivational and cognitive effects that mobile learning games enable. However, literature provides some conclusive evidence regarding the effects of mobile learning games which we summarize and discuss over the course of this chapter.

1.2.1 Basis for the analysis

We reviewed 43 empirical research articles from 2001 to 2011. We collected data from practical projects that have already been completed and which provided information across a broad range of domains (Zelkowitz and Wallace, 1998). Our focus was on mobile learning games designed for teaching and learning (educational games or serious games) with a defined learning outcome. The terms used in the search therefore included the following keywords: mobile educational game, mobile serious game, mobile learning game, mobile game-based learning (location-based, ubiquitous, mixed reality, augmented reality, pervasive) learning game.

Due to the educational focus of our analysis we excluded 4 papers that had no explicit focus on learning (Table 1.1, E.1), e.g. the study by Falk et al. (2001). Also, we excluded

12 studies that exclusively focused on the description of innovative technological concepts (Table 1.1, E.2), such as the approaches by Ballagas and Walz (2007), Chen and Tsai (2009), Diah et al. (2010), Ferdinand et al. (2005), Mohamudally (2006), Miloš et al. (2009), Moore et al. (2009), Martin-Dorta et al. (2010) or Yiannoutsou et al. (2009). For our purpose, an explanation of the effects in relation to individual gameplay mechanisms was crucial. We therefore excluded 9 papers that stated evaluation results on an unspecific level with regard to patterns (Table 1.1, E.3), e.g. the game contributed to increased learning and motivation (Klopfer et al., 2011; Shin et al., 2006; Wang et al., 2008) or the use of MLGs contributes to the development of collaboration skills (Sánchez and Olivares, 2011).

We imply that affordances of up-to-date mobile devices' hardware (e.g. accelerometer, dual cameras, etc.) have an impact on the game and that they are reflected in the individual design patterns composing a game. The review did not take into consideration a specific age group. The research we reviewed was conducted mainly on pupils and young adults (age range: 10-25 years). Possible variations in effect due to that range of age were not considered. Table 1.1 sums up the inclusion/exclusion criteria which we applied for the analysis.

Table 1.1 Inclusion and exclusion criteria for the analysis

Inclusion criteria	Exclusion criteria
I.1 Practical papers that reported evaluation results from pilot studies with a mobile learning game. Must have a clear focus on affective and/or cognitive learning outcomes.	E.1 Reports that involved mobile games that were not used for educational purposes.
I.2 Papers that provided comprehensive mobile learning game design descriptions. Must allow identification of mobile game design patterns.	E.2 Technical reports that exclusively focused on innovation, functionality, playability and/or usability testing.
I.3 Studies that reported on concrete learning Outcomes where the learning outcomes can be correlated with a pattern used in the game.	E.3 Papers that provided insufficient data for a pattern-effect determination.
I.4 Papers that are publicly available or archived.	

1.2.2 Theoretical framework

In order to describe the interplay and dependencies of game design patterns and learning outcomes, we suggest a classification framework which comprises two components:

- The Game Design Patterns for Mobile Games established by Davidsson et al. (2004)
- The taxonomy of learning outcomes established by Bloom (1956)

On the one hand, the analysis was carried out on the basis of the patterns described by Davidsson et al. (2004). As an advancement to the work of Björk and Holopainen (2004), who established an initial set of more than 200 game design patterns for computer games, the approach by Davidsson et al. describes gameplay mechanics of mobile games. The patterns provide a common language for industry and academia and help describe the rapidly developing area of mobile games. Each pattern is identified by a a core definition, a general definition, example(s), descriptions of how to use the pattern (by listing related patterns or patterns that can be linked to it), the description of its consequences, relations with regard to instantiation (patterns causing each other's presence) and modulation (patterns influencing each other), as well as references.

The pattern *Physical Navigation*, for example, "forces players of a mobile game to move or turn around in the physical world in order to successfully play the game" (Davidsson et al., 2004, p.18). The MLG "Frequentie 1550" (Akkerman et al., 2009), for instance, uses this pattern. Players have to move around to find sources of information and to complete tasks. Also, "Explore" (Costabile et al., 2008) makes use of this pattern. It requires groups to walk around the ruins trying to identify the place the mission refers to.

The pattern *Physical Navigation* is instantiated by (caused by the use of), e.g., the pattern Player-Player Proximity, Player-Artifact Proximity, Player-Location Proximity and *Artifact-Artifact Proximity*. The pattern *Player-Location Proximity* in turn is defined by the distance between the player and a certain physical location which can affect gameplay and trigger an event. "Frequentie 1550" makes use of this pattern. On entering one of the six areas the old city of Amsterdam is divided into (each area dealing with a different theme in medieval times), an introductory video clip is provided. The video clip presents words that can help to complete the assignments in that area (Akkerman et al., 2009).

On the other hand, we classified the effects extricated from the empirical studies according to learning outcomes. A learning outcome is the specification of what the successful learner is expected to be able to do at the end of the module/course unit or qualification (Adam, 2004). Learning outcome orientation can be seen within a wider trend in educational technology. One of its main ideas is to prepare students for the requirements of professional life (Vander Ark, 2002). Rather than defining the resources to be used during the learning process, outcome-oriented learning scenarios focus on the results of the educational process, e.g. the skills and content students are able to demonstrate. To depict the various learning outcomes, we applied Bloom's taxonomy (Bloom, 1956) which sorts learning outcomes into three domains:

- affective domain - motivational learning outcomes
- cognitive domain - knowledge learning outcomes
- psychomotor domain - manual/physical learning outcomes

According to Bloom, the affective domain encompasses attitudes and motivation. The cognitive domain deals with the recall or recognition of knowledge and the development of intellectual abilities and skills. The psychomotor domain encompasses manual or physical skills or the performance of actions. For the review we focused on motivational and knowledge learning outcomes. Learning outcomes that relate to manual or physical learning outcomes, e.g. exergames (Lucht et al., 2010; Yang and Foley, 2011) or console games were not considered, as they have a different didactic approach.

For the cognitive domain, Bloom distinguishes six successive levels that can be fostered - *Knowledge* (e.g. observation and recall of information, knowledge of dates, events and places), *Comprehension* (understanding information, grasping meanings or ordering, grouping, inferring causes), *Application* (using learned material in new situations, putting ideas and concepts to work in solving problems), *Analysis* (breaking down information into its components, understanding organizational structure), *Synthesis* (putting parts together) and *Evaluation* (judging the value of material for a given purpose).

The framework described above provides the basis for categorizing gameplay mechanics according to learning outcomes. From this categorization we expect to enable a rather specific use of gameplay elements. We aim at defining which patterns support (a) motivational learning outcomes and (b) cognitive learning outcomes in the six categories from least complex (knowledge) to most complex (evaluation).

1.3 Results of the analysis

In the following section, we present the results of the literature survey. In a first step, we scrutinized what games impact motivation (affective learning outcomes) and knowledge (cognitive learning outcomes). We then went into detail, focusing on the patterns used in the games and how they impact motivation or knowledge. The mobile learning game

"ARGuing", for example, impacts both affective and cognitive learning outcomes. From the study by Connolly et al. (2011) we identified the following patterns: *Augmented Reality, Collaborative Actions, Cooperation, Communication Channels, Competition, Imperfect Information, Memorability* and *Avatar*. For the pattern *Augmented Reality* we were able to extricate effects with regard to motivational and cognitive learning outcomes (see Table 1.2 and Table 1.4), e.g. the pattern *Augmented Reality* impacts affective learning outcomes: Learners are motivated to learn a foreign language. The following sections list our findings from reviewing the literature by patterns and present the effects we identified.

1.3.1 Affective learning outcomes

The literature found in the course of this review indicates that MLGs have strong motivational effects. In traditional instructional design, the concept of motivation is vital for the process of learning: In order to initialize learning and subsequently to successfully process knowledge, motivation is crucial (Klauer and Leutner, 2007). In the course of our analysis, we identified several patterns that positively influence motivation both in terms of fun as well as getting engaged with a learning environment or a certain topic to develop intellectual abilities and skills. Table 1.2 lists these patterns, describes them and presents their effects. The descriptions are taken from the pattern lists by Davidsson et al. (2004) and Björk and Holopainen (2004).

Table 1.2 Effects of mobile gaming patterns with regard to affective learning outcomes

Pattern	Pattern description	Affective learning outcome
Agents	Entities controlled by the game system, e.g. to support narrative structure.	Students are motivated to deal with the learning material (Liu and Chu, 2010).
Augmented Reality (AR)	Players' perception of the game world is created by augmenting their perception of the real world.	Students feel "personally embodied" in the game. Their actions in the game are intrinsically motivated (Rosenbaum et al., 2006). Learners are engaged and motivated to learn and use foreign languages (Connolly et al., 2011). Learners are attentive (Wijers et al., 2010). Students are mentally ready for learning (Schwabe et al., 2005). Players immerse themselves in the game (Carrigy et al., 2010).

Continued on next page

Table 1.2 Affective learning outcomes – *Continued from previous page*

Pattern	Pattern description	Affective learning outcome
Collaborative Actions	Two or more players being at the same location at the same time or attacking a target simultaneously.	Students are engaged in the game (Costabile et al., 2008; Dunleavy et al., 2009; Liu and Chu, 2010; Rosenbaum et al., 2006). Students exchange and discuss game progress (Klopfer and Squire, 2007).
Cooperation	Players are forced to work together in order to progress in the game.	Participants are driven by a good team spirit (Costabile et al., 2008). Players interact more with the object of learning (Sedano et al., 2007).
Extra Game Information	Information is provided within the game that concerns subjects outside the game world.	Players are curious and interested in the game (Sedano et al., 2007).
Imperfect Information	One aspect of information about the total game situation is not fully known to a player.	Participants are eager to finish the game (Sedano et al., 2007). Players immersed in the narrative (Carrigy et al., 2010).
Perfect Information	The player has full and reliable access to information about a game component.	Students are engaged in the game (Admiraal et al., 2011).
Pervasive Games	Play sessions coexists with other activities, either temporally or spatially.	Participants are exceptionally activated (Markovic et al., 2007). Learners are motivated to play the game (Connolly et al., 2011). Students' attitude towards learning material improves (Markovic et al., 2007).
Physical Navigation	Players have to move or turn around in the physical world in order to successfully play the game.	Students are highly motivated (Dunleavy et al., 2009). Participants are interested and moved (Schwabe et al., 2005). Students' are exited (Facer et al., 2004).
Predefined Goals	The goal is explicitly or implicitly stated when the game starts. When the goal is fulfilled, the game is over.	Students are engaged in the game (Admiraal et al., 2011).

Continued on next page

Table 1.2 Affective learning outcomes – *Continued from previous page*

Pattern	Pattern description	Affective learning outcome
Score	Numerical representation of the player's success in the game, often also defining it.	Students are motivated to deal with content on a regular basis, positive peer pressure (Douch et al., 2010).
Social Interaction	Players have the possibility to meet face to face.	Students are engaged in discussion (Klopfer and Squire, 2007).

The patterns *Avatar, Competition* and *Roleplaying* are not part of the revised list by Davidsson et al. (2004). They are part of the original list of Game Design Patterns provided by Björk and Holopainen (2004). However, the patterns seemed to be relevant for the design of mobile learning games too. We therefore included them in the study (see Table 1.3).

Table 1.3 Effects of game design patterns with regard to affective learning outcomes

Pattern	Pattern description	Affective learning outcome
Avatar	Game element which is tightly connected to the player's success and failure in the game.	Students identify with the game characters (Winkler et al., 2008).
Competition	Struggle between players or against the game system to achieve a certain goal where performance can be measured.	Students are engaged in the game (Wijers et al., 2010). Students are focused and attentive (Admiraal et al., 2011).
Roleplaying	Players have characters with at least somewhat fleshed-out personalities. The play is centered on making decisions on how these characters would take actions in staged imaginary situations.	Learners are involved in the game (Facer et al., 2004). Students feel highly engaged and identify with their roles in the game (Facer et al., 2004; Costabile et al., 2008). Students merge with the game (Rosenbaum et al., 2006). Learners are tightly associated with their tasks in the game (Rosenbaum et al., 2006; Wijers et al., 2010). Students take on an identity. They are eager to work together (Dunleavy et al., 2009). Learners feel rewarded and engaged in the game (Carrigy et al., 2010).

From the empirical studies we could ascertain that mobile learning games can help (a) to increase learners' motivation to engage with a particular learning environment, in our case this is to play the learning game (Admiraal et al., 2011; Costabile et al., 2008; Rosenbaum et al., 2006; Sedano et al., 2007) and (b) to foster students' motivation to engage in learning activities and to deal with a particular learning content (Douch et al., 2010; Markovic et al., 2007; Schwabe et al., 2005). In particular patterns such as *Cooperation, Augmented Reality, Pervasive Games* or *Physical Navigation* seem to positively influence learners' motivation to deal with a particular subject or a given learning content.

1.3.2 Cognitive learning outcomes

With regard to "hard learning" (Schwabe et al., 2005), it seems that very often the assumed positive effect of MLGs on cognitive learning outcomes cannot be substantiated. Only few studies report traceable distinctions between learning with a mobile device and learning with rather traditional instruction (e.g. regular lessons). However, some of the evaluations report on positive interrelations between learning with a mobile game and cognitive learning outcomes. In the course of our review we scanned the game descriptions and game evaluations for patterns that may cause such positive interrelations. Table 1.4 presents the results.

For the cognitive learning outcomes, we formulated the results in line with the verbs Bloom considered as suitable for describing the several levels in written objectives. Table 1.4 lists the relevant patterns and describes their assigned cognitive learning outcomes. Since Table 1.4 contains the same patterns as Table 1.2, the pattern descriptions apply accordingly.

The review revealed that only few studies empirically research the actual cognitive learning outcomes from MLGs (e.g. pre-test/post-test). Papers discuss the educational value of diverse patterns but provide little evidence that this approach leads to better learning outcomes. On the one hand, this is due to the fact that patterns have only to a limited extent been subject to explicit research. But on the other hand, studies seldom explicitly research the cognitive learning outcomes of MLGs. Many pilot studies apply qualitative measurements to evaluate effects. Further research is needed to provide a clearer picture of how individual patterns or groups of patterns function and how they effectuate cognitive learning outcomes. In order to provide an in-depth understanding of the educational effects of game design patterns for MLGs, we suggest a mixed methods evaluation, which combines quantitative and qualitative data.

Table 1.4 Effects of mobile gaming patterns with regard to cognitive learning outcomes

Pattern	Cognitive learning outcome
Collaborative Actions Cooperation	Students memorize their knowledge (Winkler et al., 2008) Students can explain and rewrite the knowledge learned (Liu and Chu, 2010).
Social Interaction	Students are able to scientifically argument (Klopfer and Squire, 2007). They can rewrite the knowledge learned (Liu and Chu, 2010).
Competition	Students can memorize the material learned (receive higher scores on the knowledge test) (Admiraal et al., 2011; Huizenga et al., 2009).
Augmented Reality (AR)	Students notice and discuss geometrical aspects of the world (Wijers et al., 2010). They can describe and illustrate a disease model (Rosenbaum et al., 2006). Students reflect on the process of learning (Costabile et al., 2008).
Pervasive Games	Students can recall the learned material (Akkerman et al., 2009). Learners are able to transfer the learned material (practical knowledge and practical experience) (Markovic et al., 2007). Students reflect on their learning. They can solve problems related to the object of learning. They can create new problems related to the object of learning. They can judge and evaluate the material for a given purpose i.e. critical thinking skills. They are able to analyze and classify the learned material (Connolly et al., 2011).
Extra-Game Information	Students can rewrite the knowledge learned (Liu and Chu, 2010).
Roleplaying	Students can give examples for the importance of communication and collaboration (Rosenbaum et al., 2006).

1.4 Conclusion and Discussion

In this chapter we have presented the findings from our review of practical research papers on the effects of mobile learning games. They indicated that mobile learning games have the potential to bring about affective as well as cognitive learning outcomes. MLGs can help to increase the motivation to engage in learning activities. With regard to "hard learning" (Schwabe et al., 2005) though, empirical evidence was fragmented.

In general, the empirical evidence in the literature we reviewed was inconsistent in terms of study design and terminology. The diverse studies had different settings with regard to the statistical base (dependent/independent variables) and the research methods they applied, as they addressed various research interests. Still, some verifiable effects were in existence. For both, affective and cognitive learning outcomes, it showed that, firstly, the impact of individual patterns on learning was difficult to determine. The studies we reviewed focused on a set of diverse patterns. This is given by definition as the use of one pattern mostly requires the presence of another game design pattern (Björk and Holopainen, 2004). From this, other complexities derived:

Does a pattern on its own have the same effect or does it require interplay with other (particular) patterns?

For example, it was stated that the provision for the pattern *Competition* positively influenced students', learning (Akkerman et al., 2009). The game additionally provided for the patterns of *Team Play, Score* and *Cooperation*, which had an impact on the competition between the groups too. Also, the affordances of the mobile devices' hardware have an impact on the pattern employed by a designer. We implied that the diverse patterns already reflect the technical possibilities. Secondly, the effects occurred with a given condition of the patterns, e.g. given time, given level, etc.:

To what extent does varying the conditions of the diverse patterns (game balancing) influence the effect?

For example, the provision of *Imperfect Information* was identified to motivate learners to finish the game:

What amount of information is necessary in order not to overstrain (discourage) or bore the learner?

In order to reduce such complexities in the pattern approach, further research on the correlations between patterns and learning outcomes has to focus on a limited number of patterns (Björk and Holopainen, 2004; Davidsson et al., 2004). Future study settings have to comprise (a) an experimental variation of patterns, i.e. game settings that enable/disable individual patterns and (b) an in-depth variation of patterns, i.e. game settings that allow for different instances of the same pattern. This way, measurable and feasible results can be obtained that are suitable as a base for design guidelines, which define (a) patterns that support the achievement of a desired learning outcome and (b) ways of applying the patterns.

Game design needs to adapt to different target groups, contexts, etc. (Adams, 2013). This in particular applies to the context of educational games. There is a vital need for tailoring learning offers (i.e. educational games) to learners' needs, capabilities and learning targets. Intelligent adaptive game patterns such as *Level* or *Score* generally reflect this need. This way, the pattern approach reflects varying target groups or contexts. A more specific analysis, e.g. the extend to which individual patterns reflect learners' needs or capabilities, is needed though. Future research needs to verify the effectiveness of mobile learning games and to corroborate their educational value in order to motivate teachers to use such tools for teaching. Otherwise, the educational system may run the risk of disengaging future learners (Klopfer et al., 2011).

1.5 Further work section

From what was mentioned above it became obvious that there is a need for more comprehensive scientific studies that scrutinize the functions of the diverse patterns mobile learning games are based on. The main research question we need to address is therefore:

How can an effective mobile learning game be developed that enhances motivation and cognitive learning outcomes?

The framework focused on two aspects: affective and cognitive learning outcomes. As for the affective learning outcomes, we identified patterns that positively impact motivational aspects. Future research will have to investigate:

How does a pattern or a group of patterns, e.g. the provision for Competition, influence the learners' motivation to actually deal with a particular subject or a given learning content?

For our research, we have to consider groups of patterns because learners seldom perceive single patterns as a game (Kelle et al., 2011). Also, the study results showed a small, though positive correlation between diverse patterns and cognitive learning outcomes. With respect to knowledge gain, this PhD work will further investigate:

To what degree does a particular pattern, e.g. Physical Navigation, increase learners' knowledge gain?

Will pupils playing mobile learning games that provide for a particular pattern have better knowledge gains than pupils receiving traditional lesson series?

A comprehensive evaluation is to follow which examines the research questions stated. It seeks to understand which specific patterns have the greatest impact on a stated learning outcome. Also, the degree of effects will be subject of future studies, for example, the degree of motivational effects of individual patterns, e.g. intrinsic versus extrinsic motivation (Schiefele and Schreyer, 1994), as well as influencing variables such as age or the prevailing level of education (i.e. educationally disadvantaged learners).

Chapter 2

Classifying Pervasive Games for Learning using Game Design Patterns and Contextual Information

This chapter further details results from the previous study by explicitly focusing on the educational potential of games that are pervasive and that utilize augmented reality (AR) to enhance the real world with virtual or naturally invisible information for their gameplay. To determine and classify possible learning outcomes it proposes employing game design patterns for mobile games and context information.

This chapter is based on: Schmitz, B., Specht, M. and Klemke, R. (2013). A Learning Outcome-oriented Approach towards Classifying Pervasive Games for Learning using Game Patterns and Contextual Information. *Journal of Mobile and Blended Learning*, 5(4), 59-71
and
Schmitz, B., Klemke, R. and Specht, M. (2012). An Analysis of the Educational Potential of Augmented Reality Games for Learning. In M. Specht, J. Multisilta, and M. Sharples (Eds.), *Proceedings of the 11th World Conference on Mobile and Contextual Learning*, pp. 140-147.

2.1 Introduction

Taken into consideration the younger generation's habits of using media, e.g. their affinity for digital games and mobile handheld technologies, traditional education has long lived a life of its own. For the last several years however, the interest of teachers and educational scientists in innovative technology for learning and teaching has grown. They have recognized the educational potential these technologies provide across varied domains and applications scenarios, i.e. setting up challenging and engaging scenarios that enable new forms of teaching and learning (Breuer and Bente, 2010; Carstens and Beck, 2010; Garrido et al., 2011; Klopfer et al., 2011; Sánchez and Olivares, 2011). Game studies and mobile technologies have thus become a fast-growing field of research. Most of the projects still centre on technological aspects though. In order to determine the factors, mechanisms and design elements that make the use of novel learning scenarios successful and transferrable, it is necessary to explore how these technologies can be used for teaching and learning (Dunleavy et al., 2009; Huizenga et al., 2009; Klopfer, 2008). In a first literature review of the field, the authors have provided a mapping of mobile games for learning onto the educational effects they provide by considering the specific design patterns used within the games (Schmitz et al., 2012b).

The objective of this chapter is to further assess and evaluate the educational potential of mobile games for learning and to better understand the specific mechanisms that have led to improved student learning and achievement. It more specifically looks at pervasive and augmented reality (AR) games for learning. Methodologically, we consider evaluation reports of games that make use of the game design patterns *Augmented Reality* and *Pervasive Games*. We line them up against Bloom's taxonomy of educational objectives (Bloom, 1956) and analyze their context parameters in order to evaluate the learning effects these games have. The results could provide valuable insight into the working mechanisms of AR and pervasive games and may positively influence future design decisions.

2.2 Pervasive and AR Games for Learning

Pervasive and game-based technologies are commonly expected to gain widespread usage for educational purposes (Johnson et al., 2011; Kelly et al., 2007; Thomas, 2006) and for the last couple of years, pervasive games have increasingly been subject to practical studies (Botella et al., 2011; Connolly et al., 2011; Laine et al., 2010; Specht et al., 2011; Tutzschke and Zukunft, 2009).

The term pervasive games is a rather "elusive concept" (Nieuwdorp, 2007, p. 14). As an umbrella concept it includes location-based and location-aware games as well as ubiquitous games or alternate reality games (Montola, 2011). It is used with a wide range of technology that spans mobile handheld-based systems running on a PDA or a smart phone as well as AR systems comprising a backpacked laptop and a head-mounted display to augment reality (Wetzel et al., 2008; Yuen and Yaoyuneyong, 2011). By now, supplementary core technologies, such as Global Positioning System (GPS), portable displays, Radio Frequency Identification (RFID) reader or augmented devices such as the smart phone's Bluetooth, Infrared or camera, are an integral part of almost any up-to-date mobile device. Thus, and because of the "increasing pervasiveness of smart phones, AR is set to become a ubiquitous commodity for leisure and mobile learning" (Specht et al., 2011, p. 117).

A core characteristic of pervasive games is that they enmesh the virtual worlds of computer games with the everyday world around us (Benford et al., 2005). "While the structure of these games is derived from a digitally created gameworld, the games are framed by the players' real-life physical surroundings and the players' interactions with these surroundings" (Thomas, 2006, p. 41) often blurring "the boundary of game and ordinary life so much that it is hard to tell where the game starts and ordinary life begins" (Montola, 2011). To depict the range of possible genres, the Integrated Project in Pervasive Games (IPerG Project) has produced pervasive game types ranging from treasure hunts and alternate reality games to smart street sports and massively multiplayer mobile games.

The object of this study has been limited to games that are pervasive and that utilize augmented reality (AR) to enhance the real world with virtual or naturally invisible information for their gameplay (Specht et al., 2011). It is geared to mobile AR as opposed to fixed or static AR, which "can be seen more in large screen displays in public spaces or through desktop computers and can generally only be used in that one specific place" (FitzGerald et al., 2012, p. 2). AR games are played in the real world, which they augment with computing functionality. This combination of real and virtual game elements creates "new and exciting gaming experiences for highly motivated learning" (Winkler et al., 2008, p. 3441). Integrating AR technology into mobile games can give educators powerful new ways to show relationships and connections (Yuen and Yaoyuneyong, 2011) and "increase learning by immersion as well as provide a richer learning experience" (Liu and Chu, 2010, p. 633).

2.3 Learning Outcomes, Patterns, and AR Taxonomies

In a prior study, Schmitz et al. (2012b) have analyzed which learning outcomes mobile games may support. Their review includes 19 well-documented game examples published in this decade, which were explicitly designed for teaching and learning (educational games or serious games). Based on the Game Design Patterns for Mobile Games (Davidsson et al., 2004), their study gives evidence that pervasive and augmented reality games especially impact motivation and knowledge gain. The review looks for validated learning effects, reported within evaluation reports of game examples, and allocates these effects to individual game design patterns. It eventually lists those effects, which can be positively assigned to a certain pattern.

Some of the game examples are explicit pervasive and/or augmented reality games. However, with regard to learning outcomes they state influence factors (patterns) other than pervasiveness or AR. The mobile game "AlienContact" by Dunleavy et al. (2009), for example, uses patterns such as *Physical Navigation*, *Augmented Reality*, *Location Artifact Proximity*, *Team Play*, *Roleplaying*, *Imperfect Information*, or *Collaborative Actions*. One of the strongest motivational effects they bring forward is the fact that AR games force pupils to go outside. "The physical exploration of the school grounds (i.e., playground, sports field, neighborhood) was highly motivating" (p. 14) and enabled students to do things (mathematics) "in a non-typical manner".

Most studies in the review refer to the patterns *Augmented Reality* and *Pervasive Games* and emphasize the motivational potential these game mechanisms provide. Based on this evidence, this chapter will take a closer look at these patterns. Both patterns have decided definitions within the approach by Davidsson et al. (2004). Accordingly, Table 2.1 presents an abridgment of the study results by Schmitz et al. (2012b). It focuses on the patterns *Augmented Reality* and *Pervasive Games*, stating the pattern descriptions, as well as the affective and learning outcomes, which the study found evidence for.

The pattern approach has become an acknowledged way of structuring and defining the complex issue of game design (Björk and Holopainen, 2004; Cook, 2010; Kelle et al., 2011; Kiili and Ketamo, 2007). Besides this approach, there have been other attempts to classify AR learning environments. FitzGerald et al. (2012) in their approach, for example, suggest a classification of AR projects from a learning perspective according to project, device or technology used, mode of interaction, method of sensory feedback to the user, personal or shared experience, fixed or portable experience and learning activity. From their analysis it shows that AR supports situated and constructivist learning especially in connection with elements of collaboration and student inquiry.

Table 2.1 Learning outcomes of the game patterns Pervasive Games and Augmented Reality. Adapted from Schmitz, Klemke, and Specht, (2012b)

Pattern/Pattern Description	Affective Learning Outcomes	Cognitive Learning Outcomes
Augmented Reality (AR) Players' perception of the game world is created by augmenting their perception of the real world.	Students feel "personally embodied" in the game. Their actions in the game are intrinsically motivated (Rosenbaum et al., 2006). Learners are engaged and motivated to learn and use foreign languages (Connolly et al., 2011). Learners are attentive (Wijers et al., 2010). Students are mentally ready for learning (Schwabe et al., 2005). Players immerse themselves in the game (Carrigy et al., 2010).	Students notice and discuss geometrical aspects of the world (Wijers et al., 2010). They can describe and illustrate a disease model (Rosenbaum et al., 2006). Students reflect on the process of learning (Costabile et al., 2008).
Pervasive Games Play sessions coexist with other activities, either temporally or spatially.	Participants are exceptionally activated (Markovic et al., 2007). Learners are motivated to play the game (Connolly et al., 2011). Students' attitude towards learning material improves (Markovic et al., 2007).	Students can recall the learned material (Akkerman et al., 2009). Learners are able to transfer the learned material (practical knowledge and practical experience) (Markovic et al., 2007). They are able to analyze and classify the learned material. Students reflect on their learning. They can solve problems related to the object of learning. They can judge and evaluate the material for a given purpose - critical thinking skills. (Connolly et al., 2011).

A connatural approach by Specht et al. (2011) classifies educational AR settings according to the educational objective and the contextual information used in the application. In their study, they describe a matrix that explicitly couples educational objectives to implementation and context. The contextual dimensions are based on an operational model of context, i.e. identity, locations, environment, relation and time. The AR patterns they identified are dynamic 3D objects, sensor-based layers, augmented books, real-world scanners collaborative tagging and annotation, and instructional AR manipulation (Specht et al., 2011).

The aspect of contextualization has increasingly been recognized for learning. Activities for learning, which are embedded in meaningful contexts, can be used to increase intrinsic motivation, even if they involve abstract operations (Cordova and Lepper, 1996).

Existing mobile technology and context-aware systems can enhance the real world and enrich the learning experience by filtering information selection and presentation, increasing the precision of information retrieval or making user interaction implicit (Specht, 2009a). In his chapter on contextualized learning services, Specht (2009b) refers to the definition of context by (Zimmermann et al., 2007). They use five categories for describing different aspects of context: individuality, time, locations, activity and relations context. Individuality context refers to information about objects and users in the real world. Time context comprises simple points in time as well as a complete history of entities. Locations context defines location models that allow working with absolute and relative positions. Activity context reflects the entities, goals, tasks, and actions and relations context describes the social, functional, and compositional relationships an entity has established to other entities.

According to Specht (2009b), contextualized information supports learning on various levels, i.e. environmental indicators of peripheral information or direct guidance. Mobile learning games use context information to enrich their contents with contextual metadata such as locations context for example. The geometry game Mobile Math is a learning game that engages students in mathematical activities through creating virtual elements by interacting with the real world. Wijers et al. (2010) use GPS functionality to link locations to geometrical shapes and also to locate fellow players in the street. Generally, contextualization facilitates the combination of different context parameters or forms of metadata about learning objects and media. This way, it enables flexible learning support, the combination of different context parameters as well as multiple perspectives and navigations paths (Specht, 2009b).

With the introduction of contextualization in our research, we aim at more precisely analyzing the mechanisms mobile learning games use and at better understanding the effects they have. Our assumption is, that the context dimension in use creates added value by influencing and varying the experience of similar patterns and thus the effect of a pattern on learning.

2.4 Theoretical Framework and Basis for the Analysis

For the analysis, we kept the basic framework as suggested by Schmitz et al. (2012b). They have employed the Game Design Patterns for Mobile Games established by Davidsson et al. (2004) and the taxonomies of educational objectives established by Bloom (1956) to better understand the learning effects of mobile learning games. In the context of our research, we expanded their basic framework by further considering a contextual dimension for the patterns as suggested by Specht (2009b). Bloom sorts learning outcomes into the three domains: (a) *the affective domain*, which comprises attitudes and motivational learning outcomes, (b) *the cognitive domain*, which deals with the recall or recognition of knowledge and the development of intellectual abilities and skills (knowledge learning outcomes) and (c) *the psychomotor domain*, which encompasses manual or physical skills and the performance of actions (manual/physical learning outcomes).

As for the cognitive learning outcomes, Bloom has defined six levels that begin with learning on the level of knowledge and advance up to comprehension, application, and the higher order skills such as analysis, synthesis and evaluation. Table 2.1 lists and formulates the learning outcomes in line with the verbs Bloom (1956) provided to more accurately determine the performance expectations of students for the distinct levels of the cognitive domain. For the level of Knowledge these are verbs such as define, know, label, list, match, memorize, name and order, for example.

We used Bloom's taxonomy because his one-dimensional list is more concise and for a first approach more applicable than the revised, two-dimensional table of Anderson (2005), for example. Future research will elaborate on how individual patterns match the advanced matrix of Cognitive Process Dimension, which modifies Bloom's categories and Knowledge Dimension, i.e. factual, conceptual, procedural and metacognitive knowledge (Anderson, 2005).For the analysis we collected data by revisiting practical projects, which reportedly made use of the game patters *Augmented Reality* and *Pervasive Games*. In the course of these projects, possible learning outcomes were tested and evaluated.

2.5 AR Games and Educational Practices

In the following section we present the results from our analysis. Tables 2.2 and 2.3 describe the patterns *Augmented Reality* and *Pervasive Games* and state corresponding game examples with domain and source. Table 2.2 lists the affective learning outcomes; Table 2.3 the cognitive learning outcomes, which we were able to extricate from the practical project papers. Furthermore, with this work, we relate the extricated learning outcomes to the usage of certain dimensions of context. As for the context dimensions we use the terms as described in Specht (2009b) as a working definition.

Our analysis of individual projects revealed, that both the patterns *Augmented Reality* and *Pervasive Games* use several context-parameters at the same time. The learning game "MobileMath", for example, uses locations context to create geometrical shapes on a previously defined playing field (map). Students create an imaginary layer on top of the physical reality. With this setting, the instructional context provides a frame to the

Table 2.2 Affective learning outcomes of AR and pervasive games and context dimensions

Pattern/ Pattern Description	Game/Domain/ Source	Affective Learning Outcomes	Context Dimensions
Augmented Reality (AR) Players' perception of the game world is created by augmenting their perception of the real world.	*VirusGame* (Outbreak@The Institute)/ Health (Rosenbaum et al., 2006)	Learners feel "personally embodied" in the game. Their actions in the game are intrinsically motivated.	Activity, Relations, Individuality
	MobileMath/Geometry/ (Wijers et al., 2010)	Learners are attentive.	Activity, Time Locations
	MobileGame/Orientation Rally (Schwabe et al., 2005)	Students are mentally ready for learning.	Activity, Locations, Individuality, Relations
	Viking Ghost Hunt/ History (Carrigy et al., 2010)	Players immerse themselves in the game.	Activity, Locations
Pervasive Games Play sessions coexist with	*ARGuing*/Language Learning (Connolly et al., 2011)	Learners are engaged and motivated to learn and use foreign languages.	Activity, Individuality
other activities, either temporally or spatially.	*Digital Economy*/ Economics (Markovic et al., 2007)	Learners attitude towards learning material improves. Learners are exceptionally activated.	Activity, Locations

artifacts and real-world objects to be learned (Specht, 2009b), which is strongly related to feedback and stimulation of metacognitive processes, for example. Also, a website is used to capture and share time context and to observe the activity of a user at a certain moment. This way, the game helps connecting real world experiences with the material to be learned and at the same time provides contextual information about locations and time, which supports the learning experience. The context dimension activity comprises the entities goals, tasks and actions (Specht, 2009b) and is a core element of pervasive and AR games. The evaluation of "MobileMath" by Wijers et al. (2010) describes AR as essential for the increase of students' attention and motivation to get engaged with a certain topic.

The "MobileGame", too, uses several context parameters such as individuality, locations or relations context. As an electronic supplement to the traditional orientation rally the "MobileGame" uses individuality context by virtually attaching tasks to real world objects on campus. The game element "map-navigation" provides the base for the orientation game. The delivery of contextual information about locations and activity of users in the game keeps participants interested and moved (Schwabe et al., 2005). Activity context asks learners to work on various tasks at significant places. According to the report by Schwabe et al. (2005) this (working on various tasks at significant places) provides the base for learners to "immerse into a mixed reality that augments both physical and social space" (p. 204).

This is substantiated by the evaluation of the pervasive learning game "Digital Economy". Here too, contextual information about locations and activity positively impacts learning. The learning game "Digital Economy" requests students to find and analyze special everyday situations via SMS. "Digital Economy" too employs a website to share learner contributions and to observe the activity of a user at a certain moment. In their study, Markovic et al. (2007) report that the pervasive game produces a higher degree of activation, more positive emotions, an improved attitude towards learning material, and also greater learning success" (p. 115).

Contextualized learning games allow for learner interaction in authentic contexts (Specht, 2009b). The "Virus Game" (Outbreak@The Institute) uses context parameters such as activity, individuality and relations context to engage learners with the game. It establishes social and functional relationships (relations context) by introducing different roles that interact with each other. The integration of individuality context or "personal embodiment" allows learners to identify with the game and the roles they played in the course of the game (Rosenbaum et al., 2006). Individuality context is integrated by means of a bar graph on the learners' PDA. This graph provides information about users' health. When the bar graph on the learners' PDA screen started to drop, for example, they spoke and acted as though they were actually sick. Also, players who were not sick responded to sick players with fear and alarm and tried to physically move away from them (Rosenbaum et al., 2006).

As for the cognitive learning outcomes, the practical studies referred to different levels of learning outcomes. Table 2.3 lists the cognitive learning outcomes aligned to the list of verbs provided by Bloom, thus suggesting a relation of the effects to the different levels. Many of the learning outcomes are of lower order. Still, AR and pervasive games can lift students into the higher order outcomes such as evaluate and create (Connolly et al., 2011), which are more complex and abstract. Context information about locations is a natural element of AR and pervasive games. Orientation rallies or games that support the exploration of sites, for example, implement context information to display map overlays or to filter information objects. The roleplaying game "Frequency 1550", for example, supports the city history curriculum at the Montessori school in Amsterdam, blends Internet and mobile phone game-play with location-based interactions. Context-parameters are used concurrently. Locations context is used to explore, map and gain knowledge of the individual areas of medieval Amsterdam and their associated themes. Students create an imaginary layer on top of the physical reality. Also, a website is used to capture and share time context and also to observe the activity of a user at a certain moment. Two maps are provided, one about medieval Amsterdam and one about present Amsterdam, that have colored dots indicating the routes of team members

Table 2.3 Cognitive learning outcomes of AR and pervasive games and context dimensions

Pattern/Pattern Description	Game/Domain/Source	Cognitive Learning Outcomes	Context Dimensions
Augmented Reality (AR) Players' perception of the game world is created by augmenting their perception of the real world.	*Time Warp*/History (Blum et al., 2012)	Learners understand spatial attributes (size and location) of a specific object.	Activity, Locations
	Virus Game (Outbreak@The Institute)/ Health/ (Rosenbaum et al., 2006)	Learners can describe and illustrate a disease model.	Activity, Relations, Individuality
	Explore!/History (Costabile et al., 2008)	Students reflect on the process of learning.	Activity, Locations, Time
Pervasive Games Play sessions coexists with other activities, either temporally or spatially.	*Digital Economy*/ Economics (Markovic et al., 2007)	Learners are able to transfer the learned material (practical knowledge and practical experience).	Activity, Locations
	Frequency 1550/History (Akkerman et al., 2009; Admiraal et al., 2011)	Students can recall the learned material.	Activity, Relations, Locations, Time
	ARGuing/Language Learning (Connolly et al., 2011)	Learners are able to analyze and classify the learned material. Students can solve problems related to the object of learning. They can create new problems related to the object of learning. They can judge and evaluate the material for a given purpose - critical thinking skills.	Activity, Individuality

Blum et al. (2012) evaluated "TimeWarp", a game that uses UMPCs to provide an AR view of the environment. "TimeWarp" uses context parameters such as locations, activity and time context to explore the medieval history of Cologne. Context information on time is a core component of the game play ranging from roman time to medieval time and the future. Time context in the course of "TimeWarp" frames the learning and is coupled with activity context. Each time period holds a challenge for the learner. "TimeWarp" also provides context information on locations. A map shows the players' current position as soon as they get within range of interesting places marked on the map and virtual objects are overlaid on the live camera image of the UMPC. From the game evaluation the authors infer that this provides perfect opportunity to "increase the understanding of size and location of a specific object. [...] Including objects of a size that forces players to walk around them to fully take them in is one possible option". (p. 718).

2.6 Discussion

In the course of our analysis, we identified interrelations between game design patterns, context information and learning outcomes. From the game examples it showed that context information impacted and varied the use of a pattern (different pattern instances) and that these variations or contextualized patterns referred to different aspects within the process of learning.

Findings provided evidence that the appropriate use of context information has potential to increase the motivational appeal of educational game contents. Within the process of learning this refers to the initial consideration whether context information has potential to make the instructional material more intrinsically interesting (Cordova and Lepper, 1996). The pervasive and AR game patterns enabled attention, activation, motivation, attitude and identification. They made use of several context parameters such as activity, relations or individuality context. The study by Rosenbaum et al. (2006), for example, referred to motivation in the sense of intrinsic motivation. Their evaluation linked motivation to the aspect of identification or "personal embodiment" within the game, which originated from learners' identification with the game and the roles they played in the course of the game. Furthermore, there was mention of attention and activation, which was used in the sense of attention and activation as a base for engagement (Markovic et al., 2007; Wijers et al., 2010). The mention of motivation and attitude referred to the aspect of learners' motivation to deal with the instructional material (Markovic et al., 2007) respective the game (Connolly et al., 2011). Educational psychologists put forth the argument that the decline in intrinsic motivation is mostly due to the decontextualization of instruction. The converse argument, i.e. that the appropriate use of contextualization is one of the many techniques with which it is possible to increase intrinsic motivation (Cordova and Lepper, 1996), further strengthens our findings. AR and pervasive games naturally used context information, e.g. locations or relations context, within their game play.

Also, the practical papers provided information on the potential to increase knowledge gain. Relations context, for example, was a strong component within games for it may have triggered empathetic arousal and enabled perspective taking, which again abeted active learning. The wide range of technology implemented in pervasive and AR games ideally benefits this component. The consideration of contextual information on the learners' (game) identity together with information about relations was a frequently used element in AR games (Dunleavy et al., 2009, Facer et al., 2004, Fotouhi-Ghazvini, et al., 2009). Matching patterns and context information indicated that context parameters, which implied educational benefits, were used to frame the learning process, e.g. context information on time (Blum et al., 2012) or context information on relations (Rosenbaum et al., 2005). Framing processes relate the content that is displayed to other content or meta-information thus linking information (Specht, 2009a). Locations context usually functions as synchronizing instance, i.e. at certain instances or places within the game-play the user and digital artefacts are synchronized thus enabling the delivery of specific information at specific places or periods in time, e.g. the game-play of "TimeWarp" and "Digital Economy". Context information about locations as seen from an educational point of view is "strongly related to the inquiry-based approaches to learning support" (Specht et al., 2011, p.122).

However, the games we presented were not explicitly designed on the base of the design patterns for mobile games. Thus, terms were used interchangeably, which made a definite allocation and attribution of the effects we extricated difficult. In order to verify findings from the present study and to generalize the assumed pattern context interrelations, future research needs to scrutinize the relationship of context information and other game design patterns or groups of related patterns in-depth. Looking at individual patterns is difficult though, as games rarely employ isolated patterns but a set of diverse patterns. The "Virus Game" used patterns such as *Augmented Reality, Collaborative Actions, Common Experiences, Imperfect Information, Physical Navigation, Player-Location Proximity, Score, Team Play* and *Roleplaying*. The positive learning outcomes stated in the evaluation report could be correlated with the patterns *Augmented Reality, Collaborative Actions and Roleplaying*, for example. This is in line with related research, which argues that game design patterns should not exist alone and that choosing one game design pattern almost automatically requires the presence of other game design patterns (Kelle et al., 2011). Huizenga et al. (2009), for example, stated that the provision of the pattern *Competition* positively influenced students' learning. The game however additionally provided for the patterns *Team Play, Score* and *Cooperation*, which had an impact on the competition between the groups too. Thus, we argue that further research is needed that investigates existing dependencies between patterns and learning outcomes in order to verify the effectiveness of mobile learning games and to corroborate their educational value.

Pervasive and augmented games for learning address a broad variety of topics, target groups and educational domains. The games we included comprised domains such as history learning (Blum et al., 2012), geometry (Wijers et al., 2010), language learning (Connolly et al., 2011; Dunleavy et al., 2009) or medicine/health (Rosenbaum et al., 2006). In the course of our review we did not evaluate in-depth how the domain interacted with the design patterns and possible learning outcomes. This will be part of a more extensive analysis. Also, we did not consider possible technical or pedagogical challenges that often go together with the use of AR for learning (FitzGerald et al., 2012).

With this research, we did not intend to provide a strict one-to-one mapping of patterns to certain learning outcomes. Just as in traditional education, there is no "magic bullet" (Hattie, 2009) in the sense of one for all. Every objective goes together with an individual set of instructional approaches and techniques (Anderson, 2005). Also, educational interventions address individual groups of learners and thus learning methods need to be proved effective over and over again and if necessary, they have to be adjusted. Therefore, this research intended to offer a "display case" - like choice of options, i.e. linking patterns with possible learning outcomes and give examples for their implementation.

Last but not least, this chapter was based upon practical research frequently at the stage of prototypes. It thus faced the same perils than the underlying practical papers with regard to validity and reliability. Montola (2011) in his review on mixed-reality game prototypes analogically referred to problems frequently related to such settings, e.g. the fact that the introduction of a novel approach always leads to bias in an evaluation. Also, research with prototypes often uses small test audiences (even below n = 10), which makes generalization difficult.

2.7 Conclusion

This chapter's contribution to research in the field was threefold. First, we presented an overview of current research in the field of AR and pervasive games for learning and outlined existing approaches for classifying them. Second, we introduced a framework for further analysis and appreciation of how mobile game-based learning content can support learning. The proposed framework extended an already existing framework by linking learning outcomes, patterns and context information. Five dimensions of context information were introduced that further specified the realization of the patterns *Augmented Reality* and *Pervasive Games*. Third, we presented results from our analysis, which showed that the link between context information and learning outcome helps to better understand the effects of individual patterns and their linkage to the process of learning. Context information added further qualitative information to the pattern and as a result, varied the role of a pattern for mobile game design. The learning outcomes we identified were influenced by context parameters such as locations, activity and relations.

Generally, mapping learning outcomes, patterns and context information may lead to a better understanding of AR and pervasive games for learning. It can provide feasible results, which are suitable as a base for design guidelines that define (a) patterns, which support the achievement of a desired learning outcome and (b) ways of applying them. However, in order to better understand how mobile games support teaching and learning, further quantitative and qualitative research is needed to validate these results in regard to other design patterns for mobile games currently in existence.

Part II

Formative Studies

Chapter 3

Developing a Mobile Game Environment to Support Disadvantaged Learners

This chapter investigates how mobile learning games can address particular educational needs. It describes a location-based game approach to motivate learners, who are at-risk of dropping out of school, in dealing with a particular subject and a given learning content. Results from a prior target group analysis unfolded several prerequisites that needed to be considered in order to successfully pursue this objective. The literature review, initially presented in the course of this thesis, revealed patterns that seem to have strong potential to respond to the identified requirements and were considered for the concept.

This chapter is based on: Schmitz, B., Hoffman, M., Klemke, R., Klamma, R., Specht, M. (2012a). Developing a Mobile Game Environment to Support Disadvantaged Learners. *Proceedings of 12th IEEE International Conference on Advanced Learning Technologies (ICALT)*, Rome, Italy, p. 223-227.
and
Schmitz, B., Czauderna, A., Klemke, R., Specht, M. (2011). Game Based Learning for Computer Science Education. In: G. Van der Veer, P. Sloep, and M. Van Eekelen (Eds.), *Proceedings of the Computer Science Education Research Conference 2011*. Heerlen, The Netherlands: ACM, pp. 81-88.

3.1 Introduction

Making education accessible to everyone is a problem: Besides age, the earning capacity as well as the social background influences the use of information and communications technology (ICT) (Boes and Preiß ler, 2002; Zwiefka, 2007). As Unterfrauner et al. (2010) state, the smaller the income the smaller the penetration rate of PCs and the smaller the possibility for youths to have access to the Internet (no access point). Also, according to the JIM Study, the level of education influences the way, the computer is used. It is stated that the higher the educational background, the more likely youths are prepared to use the computer as a means for information. People with a lower educational background rather use the computer to communicate and to play games.

This is fortified by recent developments. People with a lower educational background are increasingly difficult to reach by formal teaching and learning. Their limited motivation to learn is often caused by negative learning experiences, a low frustration tolerance and poor stamina. Mobile learning environments seem to respond to the particular needs of learners difficult to reach. Studies have shown that mobile devices help them to recognize existing abilities and to develop and to improve confidence, autonomy and engagement (Douch et al., 2010; Pachler et al., 2010). Cook et al. (2007) emphasize that learning with mobile devices supports training measures because there is no stigma attached to carrying a mobile device around instead of a self-study manual, for example. Learners are more readily prepared to use these devices for learning because mobile devices are a cool thing to use.

Also, game-based learning scenarios are often referred to as motivating learning environments that meet the younger generation's needs (Ritterfeld et al., 2009), and particularly those of learners difficult to reach (Douch et al., 2010). Within the past decade, studies have analyzed and demonstrated that commercial as well as educational games (a) support constructivist learning and teaching, i.e. constructive, situated and social learning (Gee, 2007; Prensky, 2007; Berger and Marbach, 2008) and (b) almost perfectly match the determinants of intrinsic motivation (Petko, 2008; Schiefele, 1996). According to Meier and Seufert (2003), game-based learning approaches particularly make sense if the content to be learned is dry and only somewhat interesting, if the considered target group is rather difficult to motivate for learning, if the target group already has an affinity for (computer) games (e.g. younger target groups), and/or if the target group does not have the necessary competencies to deal with a Computer Based Training (CBT) or Web Based Training (WBT), e.g. the competence to act or learn self-directed.

Playing games, whether they are explicitly designed to foster the acquisition of knowledge or not, may support the development of certain strategies and skills such as problem-solving, decision-making, understanding complex systems, planning or data handling. Computer games may also support the acquisition of knowledge according to a predefined set of subject-related facts (Prensky, 2007) that can be matched against a fixed syllabus. The German research project SpITKom (www.spitkom.de), for example, supported the acquisition of IT knowledge to master the European Computer Driving Licence (ECDL).

When it comes to the development of Multiplayer Browser Games, research from Social Cognition Studies is of paramount importance. The work by Steinkuehler (2004, 2008) on Massively Multiplayer Online Games, for example, emphasizes the potential of social mechanisms for learning such as collaborative problem solving practices as well as reciprocal apprenticeship "through which individuals enculturate one another into routine and valued practices and perspectives" (Steinkuehler, 2008, p. 12). According to a study carried out by Klimmt et al. (2009), gamers like Multiplayer Browser Games because of their particular social aspects of the game play and because of their specific characteristics regarding time and flexibility ("easy-in, easy-out").

The emerging concept of "gamification" also argues along these lines (Muntean, 2011). Although this concept is mainly used to describe the improvement of user experience and user engagement in digital marketing (Deterding et al., 2011), it is increasingly recognized by educational scientists. They have started to conceive it as a powerful means to make education more fun and to boost students' interest in otherwise rather dry content (Muntean, 2011). Thus, the development of learning environments that combine mobility and gaming with learning seem to be a promising approach and first results of handheld game studies have shown positive effects on the learning outcomes (Facer et al., 2004; Shin et al., 2006). Comprehensive empirical evidence on the motivational potential and learning effects mobile game environments provide is missing though. Based on this evidence, the mobile learning game (MLG) *WeBuild* was developed. It was designed to further scrutinize how mobile game scenarios impact motivation and knowledge for disadvantaged learners, i.e. learners who are difficult to reach, hard to access or hard to engage (e.g third chance education).

WeBuild is based on a generic mobile learning game engine. It enables location-based and Google Maps Actions, Client/Server Communication, Multiple Choice Question Management and User Management. The combination of these features was required but not found within already existing game engines. According to Adams' approach of player-centric game design (Adams, 2013), the user interface (UI) of *WeBuild* was developed in several iterative cycles with the enduser being involved in the design and development process as early as possible.

In the following, the SpITKom project and its basic technical architecture is described, which constituted the source for the *WeBuild* application. Subsequently, the *WeBuild* approach is introduced, which added to it, and the technical infrastructure is outlined. Third, the underlying mobile game engine is presented and eventually, findings from the prototype testing that was carried out in order to test interface and gameplay usability, technical functionality and motivational aspects of the game design, are reported.

3.2 The SpITKom project

WeBuild is the mobile version of the Multiplayer Browser Game *BauBoss*, which was developed in the course of the German BMBF-project SpITKom (Schmitz and Czauderna, 2011). It aimed at utilizing the acknowledged pedagogical potential computer games provide (Gee, 2007; Prensky, 2007). SpITKom was directed at supporting the acquisition of IT knowledge, this way preparing and enabling educationally disadvantaged learners to find an apprenticeship. In addition, SpITKom aimed at supporting the acquisition of practical knowledge related to the building industry. By building on the learning potential of collaboration and reciprocal apprenticeship (Steinkuehler, 2008), the project targeted at bringing forward the participants' professional and social competence. The game was directed to the building industry, this way supporting the development of a professional identity. The main user interfaces for the learner are the browser-based learning game (see Figure 3.1) and the IT-Cafe (see Figure 3.2).

The game guides the learner through building- and construction-projects. Its main intention is to bring the target group (learners difficult to reach) "in touch" with the integrated IT-knowledge. A more elaborate engagement, i.e. the actual learning, takes place within the IT-Cafe. In the course of the game, test items related to IT knowledge (ECDL) are displayed to the user. The answers influence the game play (score, money). By matching the ECDL learning outcomes against the learner's concrete abilities it analyses the learners' needs and offers questions and Units of Learning in the sense of a concrete, contextualized unit of education or training (Derntl et al., 2009) that can each be traced back to a single learning outcome. The questions are rated 1 (*easy*) to 3 (*difficult*). Depending on the learner's performance (right/wrong), the system's core backend component - the CCT (Competence Checker and Trainer) which is realized through the IT-Cafe (see Figure 3.2) - chooses the follow-up question in an adaptive manner in order to rate the learner's knowledge. Also, answers of learners are collected and stored in the learner's profile. The learner can enter the IT-Cafe to perform some

Figure 3.1 *BauBoss* Browser Game

explicit learning tasks (access learning contents, perform comprehensive tests, review own profile). Additionally, the learner can communicate with co-learners and teachers.

3.2.1 Educational Objectives

SpITKom focused on the acquisition of IT-knowledge as one of the key competencies and requirements of today's labour market. It chose to integrate the ECDL as a commonly accepted standard that reflects and certifies up-to-date skills and knowledge in the use of a computer and common applications. In its standard version 5.0, the ECDL syllabus comprises 478 learning outcomes, organized in seven modules, including topics such as "Using the computer and managing files, Word processing as well as Web Browsing and Communication" (see: www.ecdl.org).

Besides IT-related skills and knowledge, SpITKom aimed at the acquisition of knowledge related to the building industry. As opposed to the ECDL, this content is not based on a fixed curriculum or a certain syllabus of instruction but is geared to the different scenarios (garage, detached house, park, etc.) as realized in the game. Every scenario was described by means of phases and their respective workflow. Building a garage, for example, comprised the phases: setting-out the building-site and stripping the topsoil, trenching for the strip foundation, casting the strip foundation, etc. For every phase additional information was available.

Figure 3.2 *BauBoss* IT-Cafe

3.2.2 Target Group

SpITKom was directed at learners difficult to reach who are participating in state funded professional qualification programs offered by the Education Centres for the Building Industry (BZB). The target group consisted of predominantly male participants aged 17 to 25. According to the target group analysis that was carried out in the beginning of the project, only a few of the participants had a school leaving certificate. Their level of literacy was very low. Also they had strong personal and social deficits that hampered or even inhibited finding an apprenticeship. Their command of the German language was poor. Also, their capacity to memorize or to concentrate on something was rather low. They had little stamina, a poor frustration and conflict tolerance and only little or no ability to work in a team or to communicate. They were not used to learn at all and they were not willing to actively participate in learning activities (Schmitz and Czauderna, 2010). Despite these similarities, the target group was not homogeneous. They had very different attitudes towards work, different working techniques, talents, expectations and cultural distinctions.

Instead of a computer, this target group is rather in possession of television and gaming consoles (Feierabend et al., 2010) and nearly all of them possess a mobile phone. Their ability to use a computer as a tool for information and/or work is comparatively low though. By now, most jobs however require at least basic skills and knowledge in the professional use of common computer applications (e.g. word processing programs). This also applies to the building industry which increasingly relies on the use of computers for day-to-day communication or logistic matters for example.

3.2.3 Basic Technical Architecture

The SpITKom system was partially based on the Open ICOPER Content Space (OICS), which was developed in the context of the ICOPER project. The OICS was based on the OpenACS platform that was available under an open source licence, as it was the case for all modules needed for running the OICS. The OICS platform offered services that integrated concepts and data for the management of sharable educational resources.

In the context of SpITKom, the webservice infrastructure of the ICOPER components were integrated into a completely new user interface (i.e. game and IT-Cafe) (Schmitz et al., 2011). In the following, the relevant OICS resource types and their respective data models as realized in the SpITKom project, are depicted.

In the OICS, learning outcome definitions captured the key characteristics of a learning outcome, independently of its use in any particular context or for any target group, using the LOD schema (Najjar, Derntl, Klobucar, Simon, Totschnig, Grant, et al., 2010). Within the context of SpITKom, the items of the ECDL syllabus were represented as LODs. They were stored in the learning outcome repository.

The OICS enabled to pull learning content from repositories through the OAI-PMH protocol (Lagoze and de Sompel, 2001) or to push content from authoring environments through a publication service with metadata described in a profile of the LOM standard. Within the context of SpITKom, the ECDL learning contents were realized as SCORM units stored in the OICS content repository.

The OICS associated assessments with learning outcomes, which allowed generating personal achievements. They were stored in the QTI format. In the course of SpITKom, the individual ECDL tests were played using the open source QTIEngine. In the OICS, personal achievement profiles allowed learners to organize their achieved learning outcomes. Evidence records related to them were stored in the PALO data format (Najjar, et al., 2010). In the course of SpITKom, assessment results delivered from the QTI-engine were stored into the profile repository, using the PALO format.

3.3 The *WeBuild* Approach

The following section describes the game engine that was developed in order to realize *WeBuild*. The *WeBuild* approach adds to the Browser Game *BauBoss* that was used in the SpITKom project. Also, it was targeted at participants of state funded professional qualification programs offered by the Education Centers for the Building Industry (Bildungszentren des Baugewerbes e.V.) and aimed at supporting the acquisition of IT knowledge as one of the key competencies and requirements of today's labor market (Hague and Williamson, 2009). Prior to the development of *BauBoss*, a study was carried out that assessed the players' computer game preferences and their competencies in playing computer games. The results of this study also influenced the design of *WeBuild*.

3.3.1 Game Design

Learner View

The concept of the location-based mobile learning game *WeBuild* was that of individuals or teams competing against each other while solving tasks. By adding virtual objects to places the target group is daily in touch with, it included a simple augmentation of physical objects. For example in the course of *WeBuild*, players had to go to the real stocks (see Figure 3.3) in order to get the material necessary for building objects (garage, houses, etc.). The objects were virtually placed on the map and had tasks or questions attached to them. Once a player came near them, the electronic attachment became visible. The player picked them by being close enough and clicking them on the map. Complementing the Multiplayer Browser Game *BauBoss*, *WeBuild* also addressed multi-user and social interaction of the target group as one of the major objectives.

To start playing, the learner had to sign in. After that, he could choose from different types of objects (e. g. houses, garages, bus stops, etc). The choice of what he could actually build was restricted by his score and/or his money available. The learner had to find places marked on the map, go there and mark them as "construction site". Building grounds could be taken only once. As soon as one player had claimed a certain spot, it was closed to other players and they were denied to take it. For each construction site, the player could select the type of building he wanted to build there. Learners could ask friends to help them building an object (e.g. subscribe as helpers), thus working in teams. For the study, this aspect was pre-arranged due to time restrictions. In the course of the game, the players got messages on the mobile device that invited them to answer a question or to tackle a task. Both, the questions and the tasks were meant to involve them with IT learning.

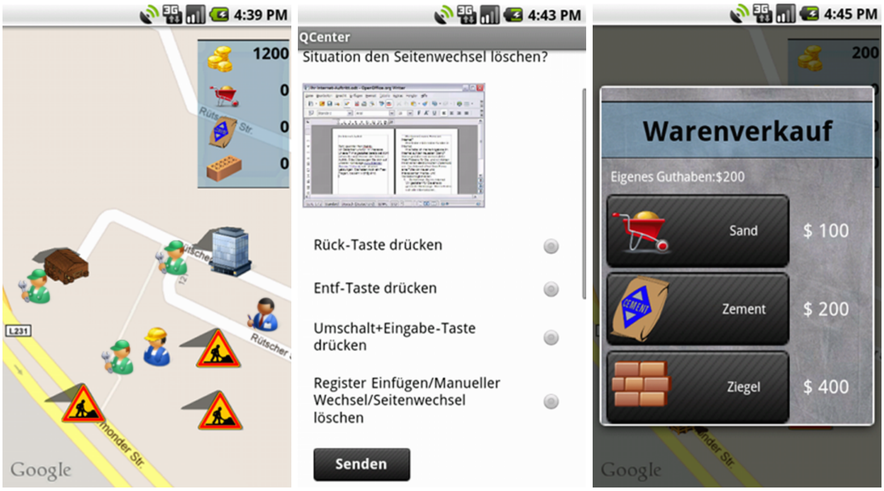

Figure 3.3 *WeBuild* game screen, question template and stocks

Also, game-based tasks and questions were integrated to motivate collaboration and to bring about commonly achieved results. For example, in the course of the construction phase, material necessary to build an object was missing at the construction site. The player thereupon received a message with the request to get the missing material, e.g. "We are running out of bricks. Get us three more packages." He then had to go to the warehouse, find the requested material and pick it. The virtual objects such as wheelbarrow, shovel, cement, mortar, etc. were virtually placed on the map. The player picked them by being close enough and clicking them on the map. If the task was finished successfully, points were granted and the object status on the virtual map updated. The social interaction in the game was assumed to attract the target group, who was very keen on playing with or against other people (Schmitz and Czauderna, 2011).

Teacher/Game Editor View

The game provided an easy-to-use map editor for teachers. With the editor, it was possible to set up a new game for a specific location and/or a specific target group. After logging in, the teacher could start the map editor. A Google Map appears. The respective location could be reached by pinch and pan touch gestures. From the taskbar on the top of the screen, the teacher could choose a point of interest (POI) type (e. g. building site, warehouse or bank) and place it on the map by tapping on the selected location. Tapping on the POI again, removed it.

The menu enabled specific game settings such as (a) defining the name of the game or of teams, (b) enabling the compass and the satellite view or (c) saving and/or loading the game. The save-and-load functionality allowed to save the created game template to the internal storage of the Android device. After the game was created, the teacher could start the game at any time. The waiting room activity then opened in which the teacher had to wait for the players to join his game.

3.3.2 Technical Infrastructure

Web Service

The MLG *WeBuild* complemented the Multiplayer Browser Game *BauBoss* that was developed in the course of SpITKom. The SpITKom architecture comprised two main components: the front-end community platform and the OICS learning service component. The community platform was based on the LifeRay open source community server and contained the flash-based game front-end. Additionally, the open source QTIEngine (http://www.qtitools.org/landingPages/QTIEngine) was integrated to visualize and evaluate assessments (Schmitz et al., 2011).

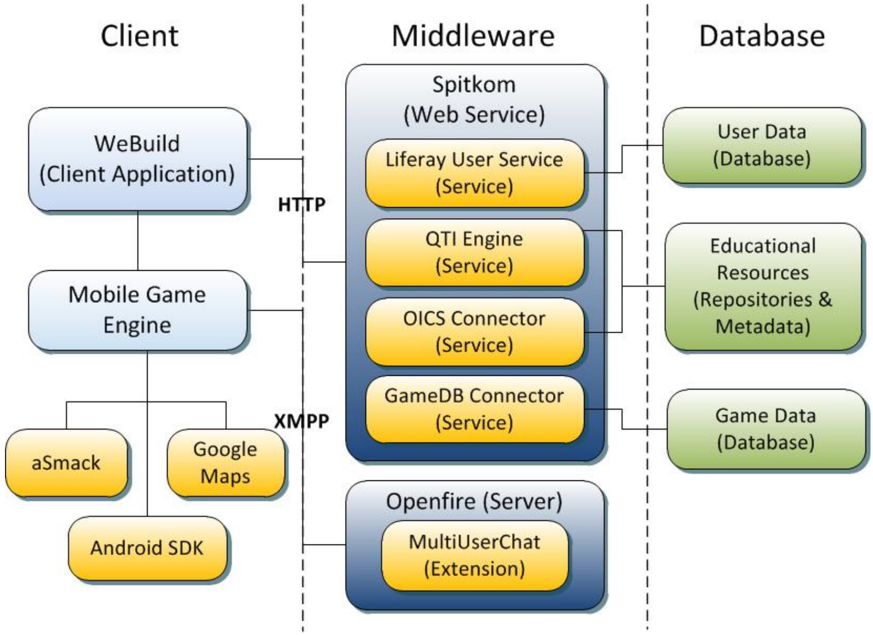

Figure 3.4 *WeBuild* technical infrastructure

The SpITKom components were addressed by a web service that wraped the four basic components: the Liferay User Service, which handled the user management, the QTIEngine, which provided an XHTML representation of a question, an OICS Connector, which was responsible for storing (and loading) learning outcomes and assessment records and a GameDB Connector that stored (and loads) game data. A HTTP connection was used to contact the SpITKom web service. Figure 3.4 represents the *WeBuild* infrastructure and points out the relations and connections between the individual components.

The mobile application was based on three Java libraries: (a) Google Maps for realizing the location-based feature, (b) Smack for realizing the multiplayer feature and (c) the mobile learning game engine developed in the course of this project. The mobile game engine served as base and provided most of the functionalities, i.e. (a) location-based features build on the Google Maps API, (b) the Question Management to handle questions in the QTI format, (c) the User Management to realize a simple user object or a complete group/team of users and (d) an XMPP Connection Manager that established and manages the XMPP connection.

The pilot used GPS for positioning with a resulting accuracy of three to five meters. The players were located and displayed as overlay objects on a Google Map. Initially, an accurate location of the player was required to open building sites, to answer questions (bank) or to get construction material from the storage.

Because *WeBuild* was designed as a multiplayer game with chat functionality, it was decided to use a Client/Server architecture with the XML-based messaging protocol XMPP (www.xmpp.org) handling the chat and application communication (Kovachev et al., 2012). Compared to the HTTP protocol, XMPP it is not stateless. This way, the established connection allowed a bidirectional communication between client and server. Furthermore, XMPP already provides several protocol extensions, called XEPs which the game engine made use of, thus opening a new Multi-User Chat (MUC) (http://xmpp.org/extensions/xep-0045.html) for each created game.

The Mobile Game Engine

The large diversity of platforms on the market makes it increasingly difficult to support all of them. In the context of this research, we decided to develop for the mobile operating system Android Version 2.1 (API Level 7) and higher which can be executed on more than 98% of the currently active Android devices (http://developer.android.com/resources/dashboard/platform-versions.html). As Software Development Kit (SDK), we chose the Android SDK in combination with eclipse.

Game engines for the Android operating system were already available. They usually focused on the display of graphic objects or the handling of touch gestures. Only a few existing game engines provided a multiplayer feature (usually implemented by HTTP polling of the client). None of them could parse and natively handle QTI questions. This was one of the main requirements for the MLG though. We therefore developed a game engine that reflected these features.

The game engine consisted of five Java package folders. The four main features were split into separate folders each. They comprised (a) location-based and Google Maps Actions, (b) the display of Multiple Choice Question (QTI format), (c) Client/Server Communication and (d) User Management. The fifth folder contained useful tools to ease the implementation process.

(a) Location-based and Google Maps Action

Handling of Overlay Objects. The game engine provided a data structure called POIContainer that could be used to group POIs together. Beside group operations the POIContainer could also be attached to a MapView.

Handling of Proximity Alerts. A proximity alert was set to a POI. Thus, an alarm was triggered if the user got close enough to this POI. Additionally, it was possible to activate a vibration alert to inform the user that he was close to a POI.

Displaying Positions. A Google Map displayed a specific overlay object that represented the players' location. This object could be replaced by a custom user graphic.

(b) Multiple Choice Question Management

Because the SpITKom project has chosen to integrate questions by way of the Question and Test Interoperability specification (QTI), the MLG had to enable this standard too. QTI is based on XML and can be used to describe assessment records.

The game engine integrated a QTIParser that translated a QTI string into a QTIQuestion object. The QTI string could be either produced by reading from a local file or by a web request. The developed game engine supported single choice and multiple choice questions.

(c) Client/Server Communication Handling

The game engine provided an object called XMPPConnectionManager. This object could be used to establish an XMPP connection to an XMPP server. In addition, it provided methods to create or join a MultiUserChat and to send messages.

(d) User Management

The user management was realized by two data structures. The object User that contained all information necessary for a user and the object UserGroup that extends an ArrayList and could handle a group (or team) of users. It implemented several methods to simplify the user group handling, e.g. displaying of team members only.

3.4 Prototype Testing

In July 2011, a test was carried out that assessed (a) the *WeBuild* interface and game-play usability (i.e. the integrated features of the prototype), (b) the technical functionality and (c) the motivational aspects of the game design. The six male participants that explored the prototype were aged between 17 and 20 years.

The testing was conducted in order to identify problems that could be addressed prior to the planned larger study. It took place at the Bildungszentren des Baugewerbes (BZB) in Duisburg, which are located in the North Duisburg Landscape Park. This area is characterized by vast places without car traffic that could possibly hamper the game actions. The POIs were defined prior to the testing. The real storage depot of the BZB was chosen as warehouse. The bank was positioned at a restaurant. The distance between the warehouse POI and the bank POI was around 300 meters. Also ten construction sites were located in between and around the bank and the warehouse. When choosing the POIs, we had to make sure that they were not too far away from each other. We suspected that in this case players would easily lose interest in the game. On the other hand, placing the POIs too close together would possibly enable them to play whilst standing.

3.4.1 Method

There were six HTC Desire mobile phones available for the game play. The phones were equipped with digital compass, Quad-Band UMTS connection, a touch-sensitive screen with multi-touch screen display and 1 GHz CPU Processing Speed. The phones were handed out to the participants for the one-hour gaming session. Before the testing, the game was installed on the devices and SIM cards were inserted in order to set up an online connection.

The participants were equipped with a smartphone each and randomly assigned to two groups of three. Prior to the game testing, the aim of the game was explained and gaming instructions were given. After the instructions the two groups were asked to play for up to an hour. During this time, intervention was kept to a minimum and only made sure that the players got through to all relevant aspects of the game play.

Qualitative data were collected by using a questionnaire and informal interviews (with the teacher and with the students). The researcher's role during the case study was participant observer. The data we collected were analyzed with regard to usability, technology use and students' participation and motivation.

3.4.2 Findings

The game testing showed that the MLG is accepted and that it has potential to motivate the target group. Also, the testing delivered valuable feedback with regard to the features we integrated.

Interface and game play usability

Participants thought that the game was intuitive. They thought that the functionalities were integrated well and that the game play was easy to understand. However, two problems were identified with regard to the game play: participants' ability for navigating with map-based applications was misjudged as was their knowledge with regard to the Android operating system.

The Google Map, which was integrated in the game, showed players' location and the positions of the several POIs. Participants had problems identifying which direction they needed to go in order to reach the targets, though. This problem was addressed by adding a compass that can be enabled or disabled by using the menu. Additionally, the option to enable Google's satellite map view was integrated which was assumed to ease orientation, because it visualizes the environment on the map.

Technical functionality

WeBuild's complex technical infrastructure proved to run capable. The generic mobile learning game engine, that formed the basis of the application, facilitated to set up a motivating and technically stable game which the players appreciated. Participants intensely used the feature for social interaction and networking (chat and application communication of the multi-player game). After the testing, some functionalities of the prototype were adapted: (1) In the future, only teachers can disable the proximity alerts. This was adjusted in order to avoid that participants erroneously switch off the location-based functionalities (proximity function). (2) The option to enable Google's satellite map view, which visualizes the environment, was integrated to ease orientation. (3) Finally, a key listener to support learners who are unfamiliar with the Android operating system was integrated. The key listener handles clicks on the return key.

Motivational aspects of the game design

From the testing it showed that the target group accepted the game. They considered it to be engaging and were motivated to use it in an educational context. Participants agreed that they would like to play the game more often. They liked the concept of the game and had fun walking around outside in teams while using the mobiles, particularly the house building feature and the chat. The distance that was chosen for the various objects (warehouse, bank, building site) seemed to be fine with the target group (radius of action < 700m).

3.5 Conclusion

In this chapter we described *WeBuild*, a mobile learning game designed to support the acquisition of IT knowledge for learners difficult to reach. The game addressed a basic understanding of computers and software applications expected universally in today's workplace. It was based on a mobile learning game engine which enabled location-based and Google Maps Actions, Client/Server Communication, the display of Multiple Choice Question (QTI format) and a User Management. A testing indicated that the game has potential to serve as an intuitive and low-threshold learning offer for the target group. Participants accepted the game and enjoyed playing it. Ongoing game testings will ensure that the game ideally meets their needs.

It is planned to use the combination of both, the MLG and the Multiplayer Browser Game, to evaluate the motivational and learning effects of coupled games. The upcoming research is based on the assumption that for the target group a coupled game is more effective than the desktop version of a learning game only. It implies that for the target group, mobile devices enable low-threshold learning possibilities, which support the acquisition of knowledge. Thus, the approach addresses a fundamental need in European education, i.e. offering new chances to those who were not able to benefit from traditional obligatory education and training, or who were not able to perform at school.

Chapter 4

Attuning a Mobile Simulation Game for School Children

The study presented in this chapter shifts focus away from target group related design issues to aspects of process-oriented learning. Based on a similar set of patterns as used in the previous study, this chapter examines individual features of a mobile game approach through which lay responders enhance their CPR skills, while expanding their procedural knowledge of how to act in case of emergency. The study was guided by the principles and attributes of design-based research and illustrates how the game has evolved from its initial conception through an iterative process of (re) designing and testing.

This chapter is based on: Schmitz, B., Klemke, R., Walhout, J. and Specht, M. (Accepted for publication in *Computers and Education*). *Attuning a mobile simulation game for school children using a design-based research approach*.

4.1 Introduction

The potential of mobile devices to engage learners and to support learning has been widely acknowledged by educational practitioners and scientists and by now, a broad range of practical studies across varied domains and application scenarios has proven the usefulness of these technologies for the process of teaching and learning (Garrido et al., 2011; Klopfer et al., 2011; Sánchez and Olivares, 2011). Mobile devices are used within various learning contexts and their functions are employed in multitudinous ways. Location-based learning scenarios, for example, make use of location-sensing capabilities to guide learners through cities or museums, asking them to pick up or capture information at predetermined locations, make inquiries, enter information and answer a series of factual questions presented to them through the mobile device (So et al., 2009). Augmented reality (AR) visuals as used in "TimeWarp" (Blum et al., 2012) or "Viking Ghost Hunt" (Carrigy et al., 2010) combine learning activities in the physical and digital environment. The switch between the two engage students' involvement with digital information by drawing the attention of learners to specific landmarks or objects for example (Dunleavy et al., 2009), this way enabling players to simultaneously focus on virtual and physical aspects of particular artefacts.

A format frequently used to take advantage of the manifold opportunities of mobile technology is mobile games for learning. For both commercial and scientific use they have been developed for various target groups and learning contexts. Research that has evaluated their educational potential found evidence for their supporting of socio-affective and cognitive learning outcomes (Kittl and Petrovic, 2008; Liu and Chu, 2010; Mitchell, 2007; Sánchez and Olivares, 2011; Schmitz et al., 2012b), or their potential to enable situated learning offers that make a meaningful and valuable contribution to the process of learning by providing aspects such as temporal flexibility, natural communication or situated learning scenarios (Klopfer, 2008).

However, using mobile devices for educational purposes faces challenges. It frequently implies a continuous shifting of attention between the different objects, tasks and activities (Rogers et al., 2009), which, for a start, interrupts the ongoing learning experience. Besides getting oriented on a screen, the learner now has to find orientation in the "real" physical environment. Learning with mobile devices differs from the learning that takes place when using desktop computing in classrooms. It is characterized by short usage sequences (e.g., entering and comparing data, looking up and reviewing information, sending texts or photos to remote people) to support foregrounded physical activities (observing, probing, measuring) in a particular environment (Rogers et al., 2009, p. 11). These seams between tasks and activities are challenges for the design of mobile learning experiences. Though the switching between the different objects, tasks and activities is sometimes credited with a potential for sensemaking activities because the device supports people in finding structure in an uncertain situation through using a combination of information, communication and computation (Rogers et al., 2009), it can be very distracting for the individual learner and might even have a share in learners' cognitive overload (Wong and Looi, 2011). Based on the cognitive theory of multimedia learning, Mayer and Moreno (2003) argue that presenting rich, diverse and complex multimedia elements at a fast rate exceeds learner's available cognitive capacity because the working memory's channels for both visual and auditory (verbal) processing are limited. As a result, engagement in substantial cognitive processing, a prerequisite for meaningful learning, is not possible. Kiili (2005), too, stresses that inappropriate ways of presenting learning material easily overload learners' working memory capacity. He notes that especially educational games run this risk because traditionally, games have consisted of rich multimedia elements. Thus, instructional design needs to consider and optimize the switch of focus between the physical world and mobile digital services to maximize the process of learning.

Especially in the field of health education this switching needs substantial consideration. Health education often takes the combination of teaching theoretical knowledge, motor skills (i.e. using a particular skill) and procedural knowledge as a basis. Traditional cardiopulmonary resuscitation (CPR) training measures, for example, strongly focus on the level of resuscitation skills, frequency of updates or contents of sessions, such as the training of CPR skills on a puppet, the right compression depth, frequency and rhythm. In order to be effective, this explicit knowledge needs to be turned into action (Jong and Ferguson-Hessler, 1996), by simulating a real emergency situation, for example.

In general, the rate of bystander CPR at cardiac arrests is comparatively low, less than 20% (Vaillancourt et al., 2008a). One of the many explanations for this is the low number of trained laypeople. In order to increase their number and thus survival rates, it is necessary to enlarge the target group for CPR training activities. Addressing school children is regarded as one toehold in this. School children are willing and prepared to provide CPR if they are trained, and they are capable of learning CPR (Lester et al., 1996). This is supported by studies which indicate that children aged 13-14 perform compressions on an unconscious patient as well as adults do (Jones et al., 2007). Organizations such as the American Heart Association expect that in the long run, mandatory training of schoolchildren at regular intervals will increase the number of trained adults (Cave et al., 2011) and will raise awareness, interest and sense of importance of taking action in out-of-hospital cardiac arrest. In their review, Plant and Taylor (2012) point out diverse methods of first aid training that have been successful with children. They state that especially the use of "virtual worlds and multiplayer online simulation could be an attractive training and/or retention tool to use in this age group" [p. 3].

In this chapter, we report research that builds upon existing evidence of the educational potential of mobile learning games. It is based on the mobile simulation game *HeartRun*, which is targeted at giving school children an understanding of cardiopulmonary resuscitation (CPR) and getting them to take action. The overarching goal is to drive research towards the design and deployment of mobile simulation games for children with a strong focus on seamless learning activities. According to the framework provided by Wong and Looi (2011), mobile assisted seamless learning activities comprise learning activities based on mobile and ubiquitous technology, which encompass formal and informal learning, personalized and social learning, physical and digital worlds. The seamless and rapid switching between multiple learning tasks or the combination of multiple devices are salient dimensions of mobile assisted learning environments. However, they are relatively unexplored from a pedagogical point of view (Wong and Looi, 2011).

This study reported here explores these issues. We examined individual features of a mobile game approach through which lay responders enhance their CPR skills, while expanding their procedural knowledge of how to act in case of emergency. Our focus is directed at children and their learning practices while learning with games. Thus, the focus that guided the studies can be formulated as follows:

How can mobile game-based learning environments be designed that support children while engaged in an ongoing task in a physical environment?

What are the characteristics of an effective mobile simulation game approach, through which lay first responders enhance their CPR skills and their readiness to help, while expanding their procedural knowledge of how to act in case of emergency?

To answer these questions, this chapter is divided into four main sections. Section 1 provides a summary of related work including a brief overview of mobile games for health, with a particular focus on games that teach basic life support (BLS) and resuscitation, including CPR. Section 2 introduces the game-concept of *HeartRun*. It describes the educational framework for the interplay of learner activities, physical environment and physical objects with the mobile device (smartphone). In the third section, we explain the methodology of three sequential studies that we carried out in order to answer research questions. We conclude with section 4, discussing and highlighting design implications for mobile simulation games that support health-related learning outcomes by enabling and facilitating seamless learning activities, which we derived from this intervention research.

4.2 Related work

For the past decade, the areas of health education and physical education have started to investigate how digital games can assist their goals, i.e. raising awareness, facilitating empathy and increasing knowledge gain (Papastergiou, 2009b). This newly created field of serious health games tries to leverage the acknowledged advantages and focuses on knowledge building, fostering positive health-related behaviours, strengthening motivation of patients to take a specific medication or to change their daily behaviour in order to live healthier lives (Gerling et al., 2011). Various innovative approaches have surfaced, such as the health game "Balance", which focuses on diabetes (Gerling et al., 2011), "Fatworld", which is used in the field of prevention and health promotion (Lampert et al., 2009), "motivotion60+" that focuses on coordination and strength exercises for fall prevention (Göbel et al., 2011) or "Re-Mission", a video game that was developed to strengthen the motivation of cancer patients to take medications (Papastergiou, 2009a).

In the past decade, several innovative games have emerged that focus on first-aid training, BLS, resuscitation training or CPR and address children, young adults and adolescents. One recent example is the crisis simulator "LIFESAVER" (https://lifesaver.org.uk/) by the Resuscitation council (UK) that fuses interactivity with live-action film. However, the actual affective and cognitive outcomes of such approaches have not been investigated in depth and need further evaluation (Papastergiou, 2009a). Still digital game-based learning approaches are motivating tools for children, young adults and adolescents. They have the potential to positively impact knowledge and are capable of changing attitude and behaviour (see Appendix A for a summary of research articles concerning digital game-based learning approaches for first-aid training, BLS and CPR).

Also, research offers little information on the effectiveness of game-based CPR instruction as against more traditional seminar based learning formats. One of the rare examples is the study conducted by Marchiori et al. (2012). They assessed the usefulness of an educational video game and compared this way of instruction to the traditional teaching of basic life support maneuvers through practical demonstrations by health care professionals. The results indicate that unsupervised use of the video-game instruction in a single 45-minute session significantly improved knowledge about the action protocol and the procedures involved.

Mobile game-based learning environments for CPR training are rarely researched, though several mobile technology-based approaches are in existence. Furthermore, as shown in Appendix A, recent innovative developments are more comprehensive such as the approach discussed by Wattanasoontorn et al. (2013). They describe a Kinect-based system for "LISSA", (LIfe Support Simulation Application), which is able to provide feedback on the performance of specific parameters of the CPR procedure (chest compression rate and correct arm position). To the best knowledge of the authors, none of the current applications uses a mobile simulation game to train BLS and CPR.

4.3 *HeartRun*: a mobile simulation game to train resuscitation

Quick decision-making and taking actions are among the most vital activities in case of emergency. By applying emergency knowledge in an innovative way, *HeartRun* uses the simulation game concept to train these skills and to engage laymen in resuscitation. In order to train and increase procedural CPR knowledge, which is based on the sequence of actions required in case of a sudden cardiac arrest, the design of *HeartRun* combines digital and physical world activities, integrates physical objects (a manikin and an automated external defibrillator (AED)), digital game-based learning tasks (e.g. data collection) and multiple learning tasks, features characteristic for the design of seamless mobile-assisted learning environments (Wong and Looi, 2011). The diverse tasks involved in the game aim at producing a more authentic context for learners than the typical classroom lecture and are envisioned as an extension of classical group-based resuscitation courses.

The effectiveness of *HeartRun*, as opposed to traditional resuscitation trainings, is arguable by drawing on the concept of embodied cognition as grounding for situatedness and context in first aid trainings. Along the theory of Jean Piaget (1964), who defines the development of sensormotoric abilities as basic requirement for cognitive development, embodied cognition argues that human cognition is deeply rooted in sensormotoric processing (Wilson, 2002). Besides relating cognition to situated activities, the concept of embodied cognition (Anderson, 2003) considers principles such as time pressure, (the need for real-time responsiveness to feedback from the environment) and action to be vital contributors for cognitive processing (Wilson, 2002). The mobile game simulation *HeartRun* supports these claims: Providing CPR and using the AED, for example, are motor activities that affect the environment in task-relevant ways. But besides situation bound cognition, which is delivered by traditional training accordingly, the design of *HeartRun* continuously requires students to take fast decisions not allowing them to "build up a full-blown mental model of the environment" (p. 628) from which they may derive a plan of action. This is argued to have "far-reaching consequences for cognitive architecture" (Wilson, 2002, p. 628) as is the case for action learning. The interactive, action driven nature of *HeartRun* inherently supports this concept, which finds its equivalence in diverse approaches such as the active learning approach (Sokoloff and Thornton, 1997).

HeartRun is organized as a list of messages that reflects the "chain of survival" paradigm used by the European Resuscitation council (https://www.erc.edu/) and thus indicates the individual steps to take in case of emergency (see Figure 4.1). Each message triggers an activity by the players or requires input in the form of video/audio messages (Kalz et al., 2013b). Students have to respond to the messages to save the victim. New messages appear as soon as the required task is completed. A CPR manikin and an AED are placed in the vicinity of the training location where participants are notified about the CPR case. The game simulation involves two roles, played by two students who make up a team:

Role A: CPR player. The messages require students to locate the victim (manikin) at the school facilities, and to provide CPR and assisted breathing. The message items of the *HeartRun* intervention that are displayed on the mobile device support them by specifying the number of compressions, the number of assisted breaths or the frequency of CPR compressions.

Role B: AED player. The messages require students to locate the closest automated external defibrillator (AED), scan the QR code next to it and go to the victim. As soon as the AED player arrives at the scene of action, the two roles synchronize, and both players now get the same messages, which require them to place the AED's electrode pads on the manikin's chest and administer the shocks while doing the heart massage.

We based *HeartRun* on the platform ARLearn (Ternier et al., 2013), an open source authoring tool suite for educators and learners. ARLearn supports the design of interactive location-based mobile games and experiences and provides functionality for:

- Role-based game environments, which enabled us to set up a realistic environment in which users are guided to an actual AED device.
- Monitoring and recording user behaviour, which is reused for later reflection and feedback on the course of action.
- Augmenting situations with location and object dependent information, processing information and notifications, as well as instructive, situation-dependent educational materials.

Augmentation in mobile games can range from eye displays that users wears as they

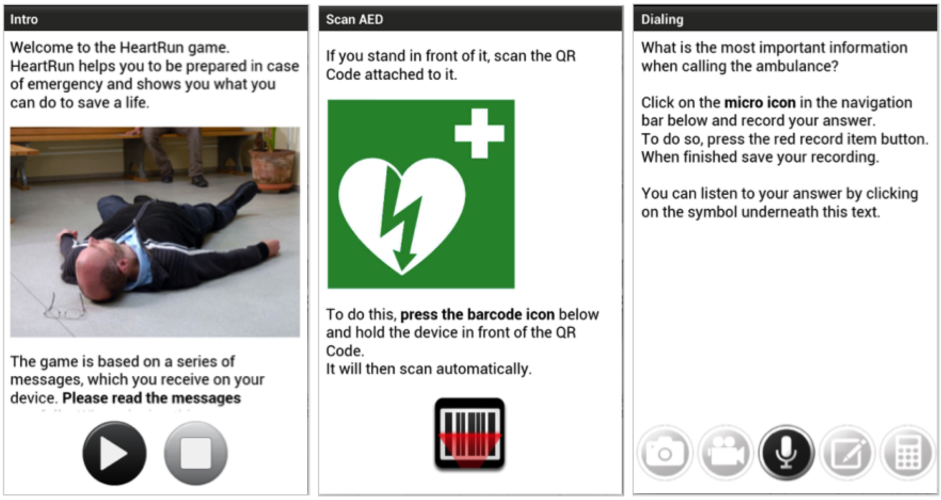

Figure 4.1 *HeartRun* welcome message, task, and instruction screen

move through the world to less obtrusive handheld technologies as we employed for our study. In accordance with existing definitions, games that augment reality create a fictional layer on top of the real world context. They are played in the real world with the support of digital devices such as PDAs or smart phones (Squire and Jan, 2007). The location-based feature of ARLearn enabled us to create a realistic setting spreading out over school. The multi-user feature enabled the provision of different player roles thus supporting team play and collaborative actions between learners.

4.4 Research Design

In order to set up the game simulation, we conducted a series of studies over the nine-month period between March 2013 and February 2014. The studies were guided by the principles and attributes of design-based research (DBR) methodologies, which focus on how concepts work in real classrooms, operated by average teachers and students, supported by realistic technological and personal support. Brown (1992) phrased it as intervention research designed to inform practice. Often seen as "test beds of innovation" (Cobb et al., 2003), design studies involve introducing an intervention in a naturalistic setting and then observing how it functions to support learning in order to better understand the procedures and instructional tools that work in real-world classrooms. "By studying a design in practice with an eye toward progressive refinement, it is possible to develop more robust designs over time" (Collins et al., 2004, p. 19). Reeves (2006) as cited in Plomp (2010) illustrated the individual steps of the underlying design process, which is depicted in Fig 4.2.

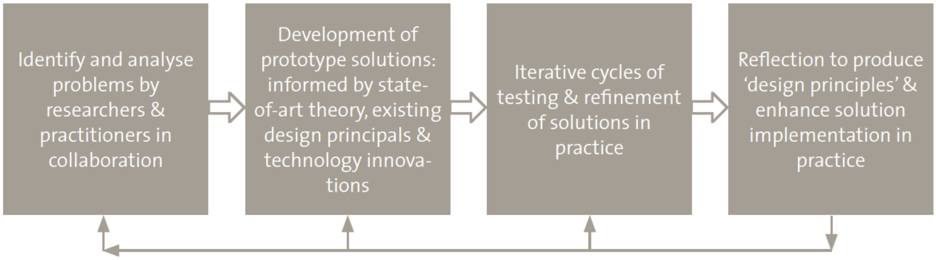

Figure 4.2 The four steps of the design process as describes by Reeves (2006) as cited in Plomp (2010)

Building on this strand of research we set up the research design. In stage one: refinement of the problem, needs were analyzed and the target group was characterized. The game concept was set up based on a review of related work and subsequently a first draft of the simulation game was introduced and continuously discussed in the context of the project EMuRgency (www.emurgency.eu).

In order to better understand the design of mobile game-based learning environments and its effectiveness we conducted several studies. The first study in our design research cycle was carried out in stage two: solutions, and was targeted at medical experts. Its aim was to secure a sound and logical setting of the prototype design from a medical point of view. In the course of the three successive trials of stage three: methods, we studied the game being played by several groups of school children with and without prior CPR knowledge. Each trial session lasted for one day with children playing in succession and comprised piloting, testing, and evaluation leading to further design refinements. In the course of stage four: design principles, we set up a list of design issues that surfaced from the analysis of study results and might guide future research in the field.

4.5 Method

Prior to the game testing we briefly explained the aim of the game and gave basic instructions on how to use the device. We then randomly assigned participants to one of the two roles (AED player and CPR player). However, the roles pupils played were not relevant for data analysis but integral part of the simulation game. A further assessment of their impact is necessary and will be addressed by future research. While playing, intervention was kept to a minimum. The researcher's role during the case study was participant observer. Participants had to fill in a questionnaire after they had played the game.

4.5.1 Data collection

For the mixed data collection we used videos and field notes of researchers' observations and conversations with participants during the activities as well as focus groups after the activity to obtain information on (a) how learners think or feel about the game simulation and (b) how to improve planning and design of the simulation game. The qualitative feedback was validated by quantitative data and was collected through a standardized questionnaire based on the system usability scale (SUS). We chose the SUS because it is an accepted measure for attitudes toward system usability (Lewis and Sauro, 2009), which makes results easily comparable. The overall SUS questionnaire is commonly used in connatural research (Wang et al., 2008). We used the standard overall SUS score, instead of the eight-item usability scale, because the overall SUS allows estimating perceived learnability along with a cleaner estimate of perceived usability (Lewis and Sauro, 2009). It provides a generic questionnaire of ten items for a simple indication of the system usability and learnability as a number on a scale from 0 to 100 points. Odd-numbered items are worded positively and even-numbered items are worded negatively. The items had to be rated on a 5-point Likert-scale. We added specific questions to the SUS with regard to suitability and perceived usefulness.

The data we collected were analyzed with regard to game usability, learnability, technology use and students' participation. Quantitative experimental data were analyzed using the statistics programming environment R and the SUS guide and calculator package (Sauro, 2011). The actual increase in knowledge (the depth of pressure or frequency of pressure rates) was not assessed. The focus of this study was purely formatively with regard to game design issues. Table 4.1 summarizes the main data collecting methods, participants and outcomes of the individual stages.

Out of the 122 SUS questionnaires we received we omitted 25 due to insufficient data, which involved missing game ID (12), missing first page (7), missing second page of the questionnaire (4) or incompleteness (2).

4.5.2 Sample

The studies benefited from contributions and feedback from a total of 156 participants. Seven medical experts from four different medical clinics - Universities of Aachen (*n*=3), Genk (*n*=1), Liege (*n*=1), and Maastricht (*n*=2) and 149 students (study 1 *n*=60, study 2 *n*=53, study 3 *n*=36).

Table 4.1 Research instruments used for the different stages and outcomes

Stage	Data collecting method	Participants	Outcomes
Stage 1 *Refinement of Problems*	Literature review Round tables	Medical experts TEL experts	Development of the conceptual model and theoretical framework.
Stage 2 *Solutions* Development of prototype solution	Prototype Testing SUS Questionnaire post activity Informal interviews with participants after the activity	Medical experts TEL experts Project staff	Models in the context of real-world problems and interventions. Theoretical contracts to guide the design process, e.g. adequacy of game features in relation to the integrated content and technical functionality. Questions for Assessment stage 3.
Stage 3 *Methods* Iterative cycles of testing and refinement of solutions in practice.	**For study 1, 2 and 3** Videos during the activity Track of game progress Field notes of researchers' observations and conversations with participants during the activities. **Added for study 2 and 3** SUS Questionnaire post activity Conversations with participants after the activities. **In addition for study 3** Focus groups	School children aged between 12 and 18 years	Learning and motivation were studied after playing the game through interviews, observations and focus groups. Hypotheses are formulated in the context of real-world problems and interventions. Validation of emergent knowledge from qualitative explorations. First set of design principles.

4.6 Iterative Design Steps

4.6.1 Prototype testing

The prototype testing was conducted on March 21st, 2013 at the general consortia meeting of the EMuRgency project in Leuven. In order to secure a sound and logical setting from a medical point of view, we tested the game prototype with medical experts (N = 7). None of them had played *HeartRun* before. The expert evaluation aimed at assessing (a) the *HeartRun* interface and game usability, with focus on adequacy of integrated game features in relation to the content ("chain of survival"), and (b) the technical functionality. To assess the prototype, we used the SUS. In order to further enhance this first feedback, we added two additional open response questions to the

SUS: "For which target group would you use the game?" and "What would you suggest to improve the game?"

For the gaming session, we equipped participants with a smart phone each and randomly assigned the players to one of the two roles (AED player and CPR player). Before the testing, we installed the game on the devices and inserted SIM cards in order to set up an online connection.

4.6.2 Findings from the prototype testing

The overall SUS for the prototype testing revealed a mean SUS score of 73.6 (*M* = 72.5, *SD* = 8.0;) and a range between 66.16 and 80.97 for 7 valid responses. The internal reliability as measured by Cronbach's alpha is calculated at 0.334. Table 4.2 indicates the average values per questionnaire item for the second study.

Table 4.2 Results SUS prototype testing, average values per questionnaire item

No	Items	*M (SD)**
1	I think that I would like to use this game frequently to train BLS.	3.43 (1.13)
2	I found the game unnecessarily complex.	2.57 (1.39)
3	I thought the game was easy to use.	4.14 (1.39)
4	I think that I would need the support of a technical person to be able to use this game.	1.71 (0.76)
5	I found the various functions in this game were well integrated.	3.86 (0.70)
6	I thought there was too much inconsistency in this game.	1.86 (1.21)
7	I would imagine that most people would learn to use this game very quickly.	4.00 (0.82)
8	I found the game very awkward to use.	2.29 (0.95)
9	I felt very confident using the game.	4.14 (0.38)
10	I needed to learn a lot of things before I could get going with this game.	1.71 (1.11)

*Assessed on a 5-point Likert-scale (1 = *strongly disagree* and 5 = *strongly agree*).

According to standardized interpretation, a SUS score above 68 is considered above average and on an adjective rating scale could be described as good to excellent (Bangor et al., 2009). In accordance with the proposition by Lewis and Sauro (2009), we analysed the overall SUS score using the two questionnaire items four and ten to assess the learnability scale and the remaining items to assess the usability scale. For perceived learnability, i.e. the ease of getting used to the application, the questionnaire yielded a mean score of 75.0. For perceived usability, the mean score was 68.8.

The expert interviews and observations showed that the game concept worked. Especially the fact that players have to quickly decide what to do in a stressful situation was rated positively. The simulation game was accepted and participants liked using it, reflecting the qualitative SUS results. In the interviews participants specified that they think the game does not replace traditional resuscitation training but ideally complements it. Participants judged the simulation game suitable for school children aged 10-16 years and young laymen (up to 20 years) as well as persons who are new to a certain environment. Feedback from the expert interviews showed that the following aspects needed to be reworked:

- Directing players in the physical world needed improvement, for instance, looking at the device to read instructions while running around to find the AED lead to them overlook the sign that indicated the device. Users suggested adding further assistance with the device and integrating directions on where to go on the phone or an audio function, for example.
- Coordinating players at the manikin needed improvement. Though participants at the manikin were dealing with the same content and were in the same location, there was little interaction between the players, who were reading in silence.
- Teaching pupils resuscitation content needed improvement. It was recommended that the message items, which mirror the chain of survival, include further medical information.

4.6.3 First study

After integrating the feedback from the prototype study into the design of *HeartRun*, the first field-study was conducted. It took place in Aachen, on July 12^{th}, 2013 at the Pius Gymnasium and was designed to assess the concept and use of *HeartRun* in a CPR training context for school children.

First, school children attended a traditional session with practical demonstrations on how to perform CPR. The training was provided by health care professionals and lasted 35 min. It comprised of a manikin and a control device that gave feedback about the depth and speed of compressions. In addition, a tutor provided feedback to the learners. Afterwards, a total of 60 students of 9th graders (between 14 and 16 years of age) were invited to participate in the simulation game. For the intervention, students were given a mobile device with ARLearn installed. We explained to them the aim of the game and gave basic instructions on how to use the device. Then the players were asked to start the game. Immediately the first message appeared and pupils started to play.

For the first study we applied a mainly qualitative approach. We combined participatory observations and conversations with participants while they were engaging in the training activities. Furthermore, activities at the manikin were video recorded to further support

Figure 4.3 Player using the *HeartRun* application at the manikin and player scanning the QR code at the defibrillator

first-hand observations. The study involved four researchers and four medical students, whose combined expertise directed the design and analysis of the mobile simulation game. They took notes of their observations and conversations with participants during and immediately after the activity. The design characteristics identified as vital for the educational intervention were systematically worked into the design.

4.6.4 Findings from the first study

Analysis of observations collected by the team showed that the actual fact of playing the game with a mobile device motivated children. Generally, they accepted the model of receiving text messages to structure the process of action, but participants did not consistently adhere to this structure. Due to connectivity problems some messages did not load correctly and/or immediately. Characteristically for many institutions, network accessibility was hampered. There was a school WLAN but students were not able to access it with their smartphones, only via private sim-cards. While adults in the prototype testing tolerated any delay, pupils simply skipped the message and carried on with the next message, thus skipping relevant content for the game play. For example, sometimes the alert message audio did not load immediately, but because pupils quickly engaged with the system, they carried on with the next message. As a result they did not know where the victim was located. The most striking aspect of learning design issues regarding the coordination of physical environment, physical objects and digital information surfaced when we analysed the game play activities at the "scene of the emergency". Four central themes emerged:

(a) **The amount of interactions that needed to be processed and the way information was presented caused high extraneous cognitive load.** The multiple- and single-choice questions that were integrated in the game to diversify the game play and to trigger reflection on the process were not recognized as such. For example, the alternative answer "Looking for a blanket to keep the victim warm" resulted in them actually looking for a blanket. They took the answer as part of the rescue process. What was unproblematic for adults proved to be impossible for children: i.e. carrying out game tasks while dealing with the manikin. Also, data that documented the game progress of individual players showed that the inquiry tasks, such as taking a photo of a potentially dangerous situation at the scene of the emergency, were easily skipped. Hence, *HeartRun* was not used in the way intended primarily because of the high workload required to complete the task-based interactions.

(b) **The switch of attention between different devices and between the digital and physical world increased cognitive workload.** The access to information in the physical world was not synchronized with the digital world. For example, the tasks and information pupils received on their mobile, for example, how to use the AED in case of emergency, was redundant. Following the instructions on the mobile phone, children turned on the AED while listening to what they were required to do next. Turning on the AED, however, started its own audio instructions for use. Additionally, this double input muted conversations between children.

(c) **The integration and realization of collaborative knowledge building depended on technical as well as individual decisions of game play.** Coordinating activities at the manikin was a difficult game task and frustrating at times (Fig. 4.3). Perhaps the most obvious problem was the organization and synchronization of the team players. When arriving at the manikin, pupils needed to scan a QR code tag to pull information and to let the system know that they had arrived at the specific location (scene of emergency). They then received text information on how to proceed. However, the individual message items of both players were not synchronized. Players read the messages at different times and at different speeds. This sometimes led to long waiting times at the manikin for one partner. Players who were standing next to each other deliberately trying to coordinate their actions were not able to do so because one partner was still dealing with previous message items.

(d) **The boundaries of technical infrastructures directly interfered with basic design decisions.** Because the children quickly got into the game play, reading the texts was not the most urgent activity to them, despite the fact that the message items contained vital information for the game. The long downloading times (items contained audio and video sequences) led to the fact that pupils did not read the texts comprehensively and easily skipped messages items. Thus, there were two important aspects of game usability that needed reworking: the notion of cognitive overload and the notion of social interaction. The initial goal of the design was to support the learning process by integrating game tasks that encouraged students to reflect, and motivating them to collaborate when helping the victim, e.g. when using the AED. However, this proved to hamper learning.

In order to achieve better results, we made improvements to the usability of already existing functions. We modified the mobile game application by:

- Adding a full audio dimension to all items,
- Lengthening the interval between the appearance of individual items,
- Considering both partners' activities for the synchronization between players at the manikin,
- Deleting the game tasks at the manikin,
- Reorganizing the synchronization of players and making it less complex.

Regarding the synchronization of team players, we reduced complexity by attuning the series of messages that show to the CPR player to the activities of the AED player. In the new game version the number of messages that show to the CPR player depend on the time, the AED player needs to get the AED and bring it to the scene of emergency. There, the AED player has to scan a QR tag. This tag informs the system and triggers the message item: The AED has arrived. The message appears for both the AED player and the CPR player regardless of the helping activity the CPR player is involved with at that time. From then on both players have 4 min to coordinate their action until the final message item appears.

4.6.5 Second study

The results of the feedback analysis from the first trial were integrated into the design of *HeartRun* and available for the second study, which was conducted in the course of the Reanimatie Estafette at Charlemagne College in Landgraaf on September 27^{th}, 2013. The second study involved a total of 53 pupils between 10 and 15 years of age (*M* = 13 years, *SD* = 1.11).

None of the pupils had played *HeartRun* before. For the gaming session, we relied on the pupils' own devices in combination with a number of smart phones we brought along. Before playing, we briefly explained the aim of the game and gave basic instructions on how to use it. Then the game was installed on the pupils' devices, or pupils were equipped with an HTC Desire mobile phone.

The main focus of study 2 was the coordination of physical environment, physical objects and digital information at the manikin in response to the analysis of study 1 activities. In order to further specify usability aspects from SUS feedback, we added questions with regard to game-play experience, the self-assessed learning outcomes, attitude towards the use of educational games and asked players for suggestions to improve the game. Activities of pupils while playing were video recorded and transcribed. The transcripts were coded and analyzed with qualitative content analysis. This feedback combined with the quantitative analysis enabled us to gain further information on how learners think or feel about the application and were the basis for the subsequent qualitative data collection of study 3.

4.6.6 Findings from the second study

The analysis of qualitative data indicated that the integration of time-critical physical tasks (running to the victim and interacting with the manikin by providing CPR) was among the strongest motivational factors. This is corroborated by quantitative data analysis as presented in Table 4.3.

Table 4.3 Results study 2, agreement of interest in game activities as a percentage of the sample

	Study 2			
What was particularly important to you when playing the game?	(N=53)	No CPR training (n=43)	CPR training (n=10)	Pearson's Chi-squared p-value
Fulfilling all the tasks	28.30	32.56	10.00	$\chi^2(1, 53) = 2.03$, $p = .154$
Acting quickly	62.26	60.47	70.00	$\chi^2(1, 53) = 0.31$, $p = .575$
Reading the text messages completely	33.96	34.89	30.00	$\chi^2(1, 53) = 0.08$, $p = .769$
Looking at the videos	33.96	39.54	10.00	$\chi^2(1, 53) = 3.16$, $p = .076$
Saving the victim's life	60.38	58.14	70.00	$\chi^2(1, 53) = 0.48$, $p = .490$
Learning how to provide CPR	39.62	41.86	30.00	$\chi^2(1, 53) = 0.48$, $p = .490$
Learning how to use the AED	49.06	55.81	20.00	$\chi^2(1, 53) = 4.16$, $p = .041$

Looking for a clearer understanding of what design elements participants valued about the application (fulfilling all the tasks, acting quickly, reading the text messages completely, looking at the videos, saving the victim's life, learning how to provide CPR and learning how to use the AED) and if this depended on whether they did or did not have resuscitation training, an inferential statistical analysis was performed. According to Pearson's chi-square test for independence algorithm, we compared all items pairwise. From Table 4.3 it shows that there was no statistically significant association between the fact that they did or did not have resuscitation training and their interest in game activities, except for item 7 (Learning how to use the AED). Participants who did not have a traditional training before reported significantly more appreciation of the AED interaction in the game $\chi^2(1, 53) = 4.16$, $p = .041$. When asked to assess what they learnt, children most frequently reported how to use the AED (59.62%), secure the scene of emergency (46.15%) and report an emergency (36.54%). All results with regard to self-assessed learning outcomes are presented in Table 4.4.

Table 4.4 Results study 2, self-assessed learning outcomes as a percentage of the sample

	Study 2			
Do you think you have learned something in the field of	(*N*=53)	No CPR training (*n*=43)	CPR training (*n*=10)	Pearson's Chi-squared p-value
Securing the scene of emergency	46.15	53.66	18.18	$\chi^2(1, 53) = 4.39$, $p = .036$
Checking the victim for a response	34.62	39.02	18.18	$\chi^2(1, 53) = 1.66$, $p = .197$
Calling emergency	36.54	36.59	36.36	$\chi^2(1, 53) = 0.00$, $p = .989$
Checking for normal breathing	25.00	21.95	36.36	$\chi^2(1, 53) = 0.96$, $p = .327$
Opening the airway	23.08	19.61	36.36	$\chi^2(1, 53) = 0.60$, $p = .239$
Providing CPR	30.77	36.59	9.10	$\chi^2(1, 53) = 3.08$, $p = .079$
Using the AED	59.62	60.98	54.55	$\chi^2(1, 53) = 0.15$, $p = .699$
Rescue Breathing	19.23	19.51	18.18	$\chi^2(1, 53) = 0.01$, $p = .921$

Pearson's chi-square test was performed to assess the overall relationship between prior resuscitation training and learners' self-assessed learning outcomes. Results indicated no significant association between this criteria and the fact that they did or did not have prior resuscitation training, with the exception of item 1 (Securing the scene of emergency), which was significant $\chi^2(1, 53) = 4.39$, $p = .036$.

The overall SUS for study 2 revealed a mean SUS score of 52.8 ($M = 55.0$, $SD = 17.20$) and a range between 48.09 and 57.57 for 53 valid responses. The internal reliability as measured by Cronbach's alpha is calculated at .747. Table 4.5 indicates the average values per questionnaire item for the second study.

The decomposed SUS questionnaire revealed a mean score of 55.2 for perceived learnability ($SD = 28.40$), and a mean SUS score of 52.2 for perceived usability, ($SD = 18.10$). A SUS score of about 55 could be considered a marginal level and on an adjective rating scale could be described as OK (Bangor, et al., 2009). After the activity, children reported that Internet connectivity was often bad and thus the videos did not

Table 4.5 SUS scores *HeartRun* study 2, average values per questionnaire item

No	Items	*M (SD)**
1	I think that I would like to use this game frequently to train BLS.	2.68 (1.11)
2	I found the game unnecessarily complex.	3.06 (1.46)
3	I thought the game was easy to use.	3.42 (1.29)
4	I think that I would need the support of a technical person to be able to use this game.	2.92 (1.55)
5	I found the various functions in this game were well integrated.	3.34 (1.06)
6	I thought there was too much inconsistency in this game.	3.15 (1.03)
7	I would imagine that most people would learn to use this game very quickly.	3.38 (1.32)
8	I found the game very awkward to use.	3.06 (1.26)
9	I felt very confident using the game.	3.17 (0.94)
10	I needed to learn a lot of things before I could get going with this game.	2.66 (1.30)

*Assessed on a 5-point Likert-scale (1 = *strongly disagree* and 5 = *strongly agree*).

show, which mainly hampered information access and caused a high degree of distraction and frustration. Still, 35 out of 53 children stated they would like to use such systems in classes more often.

Using independent samples t-tests, Table 4.6 illustrates t-test results of the two participant groups (prior CPR training and no CPR training) for each SUS scale and states the differences between them. From the analysis, no significant differences between the two groups of students showed.

Table 4.6 Contrasting mean SUS scores, standard deviation and t-test results of participants from study 2 with and without prior CPR training for each SUS scale

SUS scales	Groups	*n*	*M (SD)*	t-value (p-value)
Overall SUS	Prior CPR training	10	58.50 (18.97)	1.16 (.251)
	No CPR training	43	51.51 (16.71)	
Usability	Prior CPR training	10	58.15 (17.99)	1.15 (.271)
	No CPR training	43	50.88 (18.05)	
Learnablity	Prior CPR training	10	60.00 (27.51)	0.59 (.557)
	No CPR training	43	54.07 (28.83)	

4.6.7 Third study

Our third study integrates pupils with learning disabilities to evaluate design and implementation issues of a mobile game for learning that is meant to engage them in using such an educational tool for learning. The SEN learners comprise children with specific speech and/or language difficulties (SSLD) who are unable to express themselves in the normal effortless way, and where the difficulty cannot be attributed to physical or sensory impairments, (Bishop, 1997; Adams, Byers, Brown, and Edwards, 1997, as cited in Davis, Florian and Britain, 2004). They often have difficulties in learning to read, write and spell, in processing information and in sequencing and organizing activities.

The sample size of study 3 encompassed 36 learners with special educational needs between the ages of 12 and 18 years (M = 15.41 years, SD = 1.50). For study 3 we used quantitative techniques (questionnaire) and additional qualitative data (video recordings and focus groups). Based on the topics identified from the analysis of data from study 2, a semi-structured protocol was developed to guide the author's attention during the video observations and focus groups. The qualitative studies characterized the target group's interaction with the game simulation in relation to the learning targets. Specifically, the team was interested in how learners perceived and interacted with the physical objects and the integrated learning tasks.

4.6.8 Findings from the third study

Analysis of diverse interactions showed that for pupils of study 3 the inclusion of physical tasks was motivating and enabled participants to enhance their skills. This is substantiated by quantitative data.

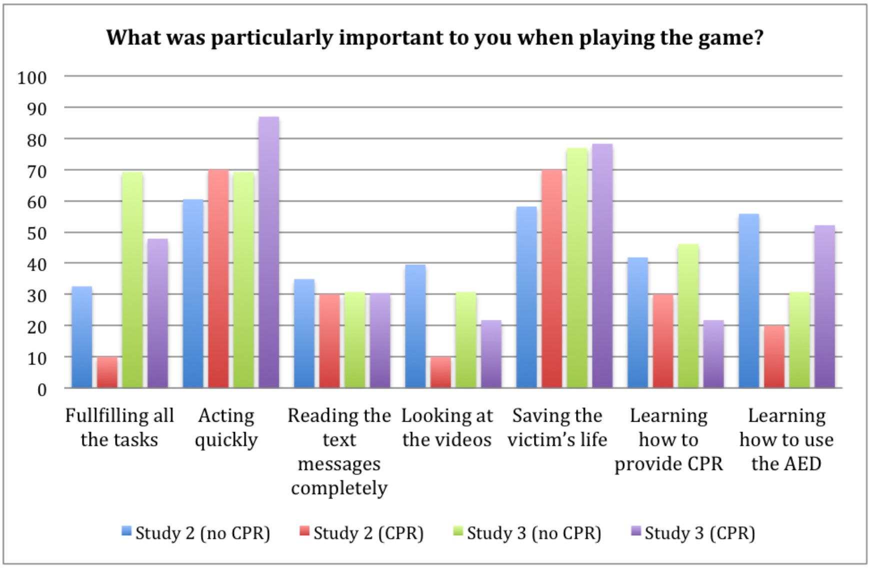

Figure 4.4 Comparison results from study 2 and 3, percentage of agreement per condition of interest in game activities

When asked in the questionnaire what was particularly important to them when playing the game, most children marked tasks related to physical activity, such as acting quickly (80.56%) and saving the victim's life (77.78%). Also, 55.56% of the participants stated that fulfilling all the tasks was important to them. Game elements such as looking at the videos were rated less important for their involvement in the game (25.00%). According to Pearson's chi-square test for independence algorithm there was no statistically significant association between pupils' interest in game activities and the fact that they did or did not have prior resuscitation training for any of the seven items. Figure 4.4 compares pupils' interest in game activities between study 2 and study 3 for individual items. Data analysis revealed a statistically relevant difference for the first two items. Pupils from study 3 (SEN learners) stated significantly greater interest in fulfilling all the tasks (χ^2(1, 89) = 5.76, p = .016) and acting quickly (χ^2(1, 89) = 3.91, p = .048) than pupils from study 2 (regular learners).

When asked to self-assess their learning outcomes, participants from study 3 most frequently stated providing CPR (59.46%), how to use the AED (59.46%) and checking the victim for a response (36.54%). Pearson's chi-square test was performed to assess the relationship between prior resuscitation training and learners' self-assessed learning outcomes. Results indicated no significant association between this criteria and the fact that they did or did not have prior resuscitation training.

Table 4.7 Comparison of results study 2 and 3, self-assessed learning outcomes as a percentage of the sample

Do you think you have learned something in the field of	Study 2 (N=53)	Study 3 (N=36)	Pearson's Chi-squared, p-value
Securing the scene of emergency	46.15	27.03	χ^2(1, 89) = 3.35, p = .067
Checking the victim for a response	34.62	37.83	χ^2(1, 89) = 0.10, p = .755
Calling emergency	36.54	32.43	χ^2(1, 89) = 0.16, p = .689
Checking for normal breathing	25.00	32.43	χ^2(1, 89) = 0.59, p = .442
Opening the airway	23.08	24.32	χ^2(1, 89) = 0.02, p = .891
Providing CPR	30.77	59.46	χ^2(1, 89) = 7.28, p = .007
Using the AED	59.62	59.46	χ^2(1, 89) < 0.001, p = .988
Rescue Breathing	19.23	18.92	χ^2(1, 89) = 0.001, p = .971

Table 4.7 compares pupils' self-assessed learning outcomes between study 2 and study 3 for individual items. It showed that pupils from study 3 (SEN learners) assessed their learning outcomes significantly better than pupils from study 2 (regular learners) for providing CPR (χ^2(1, 89) = 7.28, p = .007). Learning how to provide CPR is an activity based on context information and provided on the smartphone at the scene of

emergency in order to enrich the physical environment.

The *HeartRun* questionnaire from study 3 revealed a mean score for the overall SUS of 76.3 (*SD* = 18.60), and a range between 66.9 and 85.51 for 36 valid responses. The internal reliability as measured by Cronbach's alpha is calculated at .879. According to standardized interpretation, a SUS score above 71.4 could be described as good to excellent (Bangor et al., 2009). For perceived learnability, the questionnaire revealed a mean score of 56.3 (*SD* = 32.20). With regard to perceived usability, the feedback revealed a mean score of 81.3 (*SD* = 17.80). Table 4.8 compares the average values per questionnaire item from study 2 and 3.

Table 4.8 Comparison overall SUS scores *HeartRun* study 2 and 3

No	Items	Study 2 *M (SD)** (*N=53*)	Study 3 *M (SD)** (*N=36*)
1	I think that I would like to use this game frequently to train BLS.	2.68 (1.11)	3.89 (1.10)
2	I found the game unnecessarily complex.	3.06 (1.46)	1.92 (1.34)
3	I thought the game was easy to use.	3.42 (1.29)	3.81 (1.15)
4	I think that I would need the support of a technical person to be able to use this game.	2.92 (1.55)	2.73 (1.35)
5	I found the various functions in this game were well integrated.	3.34 (1.06)	3.97 (1.32)
6	I thought there was too much inconsistency in this game.	3.15 (1.03)	2.16 (1.12)
7	I would imagine that most people would learn to use this game very quickly.	3.38 (1.32)	4.11 (1.08)
8	I found the game very awkward to use.	3.06 (1.26)	2.03 (1.28)
9	I felt very confident using the game.	3.17 (0.94)	3.65 (1.40)
10	I needed to learn a lot of things before I could get going with this game.	2.66 (1.30)	2.76 (1.50)

*Assessed on a 5-point Likert-scale (1 = *strongly disagree* and 5 = *strongly agree*).

From the qualitative feedback it showed that participants from both study 2 and study 3 valued the list of message items because it helped them to structure the process and guided them through the course of action. However, for the SEN learners, the organization of the message items was rather problematic. They had problems connecting individual messages and tasks to the overall process: *The relationship of the messages was not clear. It was difficult to keep the overview. Maybe better use something else, like a list to check off.*

A recurring theme that emerged from the focus groups and student usage studies was the alignment of the sequence of messages to learner activities, physical environment and physical objects. The transcripts revealed the switch between device, task and physical environment to be demanding, making it difficult to integrate the task-based interactions (audio and photo entry task) that could have enabled participants to enhance their skills.

When asked for the kind of support they would have wished for in order to make the game work better for them, participants from both studies frequently replied in favor of a usage scenario of 1:2 (as in pair work, sharing a device). They argued that this way, they could compare notes. One deals with the device, the other one acts. This way both players could help each other as exemplified by the following dialogue:
S 1: *The fact that two people can make it together, running and so.*
Researcher: *Two people with one cell phone?*
S 1: *Yes*
S 2: *To discuss what to do next.*
S 1: *Yes, I think so too.*

4.7 Summary of Results and Discussion

This section discusses and highlights the implications we derived from the analysis of research data. Our findings identified critical characteristics of *HeartRun* as well as strategies required to incorporate these features in the design of mobile game-based learning environments. The claims we made were based on learning contexts, which we influenced and which had individual systemic constraints. Therefore, generalizing our findings needs careful consideration. Barab and Squire (2004) already emphasized that "contexts are never without agency; there are always teachers, administrators, students, and community members creating context and, therefore, local adaptability must be allowed for in the theory" (p. 11). Still, our research allowed to deduce design implications for mobile games for learning with a particular focus on design principles for seamless learning activities, such as learning activities based on mobile and ubiquitous technology that encompass physical and digital worlds, switching between multiple learning tasks, and ubiquitous knowledge access. To reflect these issues, we organized the discussion according to the three main design characteristics that emerged from the studies and related them to the framework provided by Wong and Looi (2011).

4.7.1 Accessing knowledge

Our studies illustrated how mobile learning games can support students while engaged in an ongoing task in a physical environment. The most supportive function was typically evident in situations of uncertainty, for example, the usage of an AED. In such instances, students resorted to information provided on the mobile device and the switch between physical environment, device and game activity was unobtrusive. Hence, one of the main benefits of using the mobile devices was to allow context information to constantly accompany and guide pupils, supporting their understanding and learning of the intended process or structure (i.e. helping in case of emergency). This also related to the aspect of how students accessed information.

A striking aspect of learning design issues surfaced when we analyzed the activities at the "scene of emergency". In a first game version, the digital device did not immediately provide participants with the necessary context information, which was needed in situations new to them. Context information supports learning on various levels by using environmental indicators of peripheral information or direct guidance, for example, (Specht, 2009b) and has potential to increase the motivational appeal of educational game contents (Schmitz et al., 2013a). In their review on pervasive games for learning, Schmitz et al. (2013) described how mobile games for learning use context information to enrich their contents with contextual metadata such as activity context, for example, by asking learners to work on various tasks at significant places thus providing an interesting and moving way for accessing knowledge.

This, however, implies the careful consideration and coordination of the possible seams between physical environment, physical objects and digital information. Mobile seamless learning designs that are directed at enabling interactions with reality and sensemaking activities need to consider this. *HeartRun* integrated aspects of this by pupils scanning a QR code tag and this way pulling context information. Their need to reflect on this information by talking to each other and their need to coordinate their action in order to help the victim was first hampered by badly synchronized information items. The download of media items on the device was one possible pathway and resulted in the delivery of relevant content at appropriate locations and times despite the lack of network coverage. Rogers et al. (2009) emphasized that in order to understand "whether a sensemaking conversation is triggered during an ongoing task and what is covered during it, depends on a number of factors, such as how unusual an observation is, how often it has been seen before, etc." (p. 122). If it is not possible for learners to make sense of new information they may eventually ignore the information as incomprehensible "noise" (Wong and Looi, 2011). This also applies to redundant information, i.e. information from objects in the physical world and digital sources of information focussing on the same task. Mobile game designs for learning need to consider the prime sources of information and synchronize or complement them.

With regard to the aspect of learning it showed that besides enabling a direct access to knowledge via context information, for example, mobile games for learning might also enhance the actual learning environment. Our studies showed that the use of digital devices may foster social interaction and that students were trying to find suitable forms of cooperation while using them. Research in the past decades has emphasized that learning is inherently a social activity (Vygotsky, 1978). The potential of mobile learning scenarios to effectively promote social interaction, thus facilitating collaborative knowledge building is frequently emphasized by research in the field (Patten et al., 2006; Sharples et al., 2009; So et al., 2009). All the more, this was relevant in our context (helping in case of emergency) because collaborative sensemaking was likely to support time-critical action and cooperation between first responders with different backgrounds (Paul et al., 2008). However, a further assessment of the quality of social interactions is necessary.

4.7.2 Integrating learning tasks

Mobile games for learning have the potential to involve children in different tasks of learning such as content generation, collaboration, problem solving or navigation in space and may thus support a wide variety of cognitive and social skills (Spikol and Milrad, 2008). Also, Wong and Looi (2011) in their review on mobile-assisted seamless learning argued in favour of integrating a variety of inquiry tasks into the mobile-assisted seamless learning flows in order to nurture 21st century skills and competencies. From a learning perspective, the integration of learning tasks is desirable, for this supports learning by facilitating reflection and thus securing knowledge. However, from the design studies it surfaced that the switch between device, task and physical environment was demanding and the task-based interactions (multiple- and single-choice questions, audio and photo entry tasks) that were integrated in order to diversify game-play and to trigger reflection on the process, which could have enabled participants to enhance their skills, were not recognized as such and easily skipped. Thus, we argue that the integration of learning tasks as a main characteristic of games for learning needs the careful consideration of previous action, context and target group. However, this dimension of mobile game-based learning environments, the seamless switch between different learning tasks, is relatively unexplored (Wong and Looi, 2011) More empirical research is needed in order to provide constructive environments that promote the active sensemaking nature of learning when coping with new situations and problems (Weick, 1995).

4.7.3 Switching between physical and digital activities

A core design element of mobile games for learning is the switch between physical and digital worlds, which frequently involves physical activity. Study results showed that the inclusion of physical activity tasks was engaging and enabled participants to enhance their skills, which is consistent with findings from previous research on engagement and learning. Blum et al. (2012), for example, reported research wherein the initial task immediately put players into action and created a physical and emotional peak, which involved players in the simulation game. However, coordinating tasks such as receiving directions on the device while running through the physical environment need careful consideration. In this context, audio emerged as a core design aspect. Setting up the task with audio instructions that direct players through the environment avoids an unnecessary switch of visual focus (looking at the device to read subsequent instructions while players are already running to get to the scene of emergency), which is also a safety issue. This especially was true for children between 11 and 14 years, who quickly became immersed in the game and acted as if they were in a real emergency situation.

4.8 Conclusions

This research reported a mobile game application where children played an active role in the simulation of a dynamic process. We provided a summary of related work including an overview of mobile games for health, with a particular focus on games that teach BLS and CPR and outlined the underlying game concept for our design-based research approach. Subsequently we described the iterative design process and deduced design implications for the development of mobile game applications for school children. In the process described above, the DBR approach was demonstrated to be valid, useful and informative in an educational context, which is verified by connatural recent research (Palalas and Anderson, 2013; Annetta et al., 2013). Likewise, this human-centric design practice offers new dimensions and opportunities to promote novel ways of learning for schools (Spikol and Milrad, 2008) and the alignment of learning interventions to the individual needs of learners (McCombs, 2000; Collins et al., 2004). Even though scientists have increasingly started to consider how technology can support the diverse needs and capacities of learners, there still is a surprising lack of systematic evaluations that investigate the benefits of the "new" communication technologies for SEN learners with more complex and severe communication and language needs (Davis et al., 2004; Williams and Nicholas, 2006).

The design implications we derived from our research indicated that mobile game-based learning environments can productively support seamless learning activities for children. Though the approach to seamless learning design is often difficult to achieve, it is worthwhile and in the context of our research unveiled valuable results that can help to bridge the gap between learning in physical and digital worlds.

So far, we have not investigated the differences in school children's knowledge gains or their attitudes towards *HeartRun* versus a more traditional seminar-based learning format. This will be part of future studies. We are currently conducting a large-scale study to evaluate the influence of *HeartRun* on behavioural outcomes.

Part III

Effects on Learning Outcomes: Empirical Findings

Chapter 5

The impact of coupled games on the learning experience of learners at-risk: An empirical study

In order to further verify findings on the assumed learning outcomes of mobile gaming patterns, two empirical studies were carried out. This chapter reports findings from the first study, which looks into an educational setting that makes use of the pattern *Coupled Games* by linking a mobile game with a PC Browser Game. The study assessed the potential of *Coupled Games* with regard to motivation and knowledge gain for learners at-risk. It showed that this pattern positively impacts students' learning and suggested that the intervention can improve students' interest in dealing with the topic.

This chapter is based on: Schmitz, B., Klemke, R., and Specht, M. (2013). The impact of coupled games on the learning experience of learners at-risk: An empirical study. Manuscript in Press for *Journal of Pervasive and Mobile Computing*.
and
Schmitz, B. Klemke, R. and Specht, M. (2014). Exploring support mechanisms for learners at-risk through a coupled game environment. *International Journal of Learning Technology*, 9(2), 202-218.

5.1 Introduction

Todays young adults have grown up using devices like computers, mobile phones, and video consoles for almost any activity. Their habits in using media strongly contrast with traditional schooling methods, which seem little motivating in the light of these devices (Klopfer et al., 2011). While young adults conduct a substantial part of their lives via the mobile phone, schools and universities have long pursued other forms of educational interaction and contact (Harley et al., 2007). However, for nearly half a decade now, digital and in particular pervasive game-based learning scenarios have started to gain traction among educational practitioners (Dunleavy et al., 2009; Laine et al., 2010; Connolly et al., 2011).

Pervasive learning games provide motivating, low-threshold learning opportunities and enable the creation of situated learning scenarios that enhance encoding and recall (Klopfer, 2008; Specht, 2009a). As Traxler (2010) points out, mobile devices provide chances to counteract social exclusion by offering learning opportunities for students "unfamiliar with and lacking confidence in formal learning and its institutions, e.g. the homeless, gypsies, marginal groups, and NEETs (Not in Education, Employment or Training)" (p. 132), providing them chances to develop and improve confidence, autonomy, and engagement (Douch et al., 2010). Especially the NEET group comprises individuals who, regardless of their educational level, are disengaged from work and education and are therefore at a higher risk of labor market and social exclusion (Mascherini, 2012). They are regularly associated with negative respondence to educational offers, difficulty adjusting to school, unacceptable social behavior, or literacy and numeracy needs (Pierce, 1994). On the basis of a multitude of cultural, social and/or socio-economic problems, these learners are at risk of dropping out of school. They have been excluded or truanted due to disaffection or bullying and often face difficult personal circumstances such as caring responsibilities, domestic violence, or learning disabilities (Simmons and Thompson, 2011). Manning and Baruth (1995) list a multitude of conditions that can place learners at-risk for educational difficulties such as school conditions (e.g., inappropriate instruction or hostile classroom environments), societal factors (e.g., society's tendency to be racist and sexist, discrimination against culturally diverse groups) or personal causes (low self-concepts, lack of motivation or problems with drugs and alcohol). The target group's personal, economic and social backgrounds have thus led to a lack of "the cognitive schemata upon which classroom instruction is ordinarily based" (Pierce, 1994, p.37). Consequently, "their opportunity of functioning successfully as adults in roles associated with work and family is jeopardized" (Richman et al., 1998, p.30). It is thus one of the main challenges for the educational system to bring these youngsters back into education and training.

From their learning history the target group has concluded that school and education are something difficult to handle. Innovative, media-based forms of learning and teaching that include mobile devices and game environments are alternative learning environments that may countervail the "alienating classroom" (Pierce, 1994) and are thus regarded as one toehold to face the challenge. Instead of providing continuously "more of the same", i.e. more homework or more reports, which is rather prejudicial to learners at-risk (Manning and Baruth, 1995), alternative learning environments allow for new experiences, outside the traditional classroom setting that comprise different forms of cooperative learning and make way for individual learning styles, for example; a description that can almost comprehensively be applied to pervasive games for learning. In general, the aspect of mobility in learning has been considered useful for the process of teaching and learning (Garrido et al., 2011; Klopfer et al., 2011; Sánchez and Olivares, 2011) and especially for this particular target group.

With this work we scrutinize how at-risk learners with different abilities and capacities can be effectively and efficiently supported by a mobile learning game. In order to do so, we employ Game Design Patterns for Mobile Games (Davidsson et al., 2004) and in the context of our ongoing research focus on the pattern *Coupled Games* (Peitz, 2004).

Coupled Games are defined as games that share some amount of player-accessible data. They "always refer to at least two games. A single game cannot be coupled. The coupling occurs when the games in question share some data" (Davidsson et al., 2004, p.14). The shared data can be anything from player specific data, virtual resources such as gold coins, to the actual world where the game takes place. The game Sonic Adventures (Sega), for example, uses this pattern. Sonic Adventures is a console game. As part of the game, players have to find Chao Eggs, which they can hatch and transfer to a Gameboy Advance. The Chao can then be raised on the mobile device and separately from the console game. The pattern *Coupled Games* is instantiated by (caused by the use of), e.g., the pattern Trans-Game Information. This pattern in turn is defined as the information that is passed from one game session to another game session. Sonic Adventure uses this pattern too. Chao go through several stages in their lives, from egg, child and adult, to death. The stages last from a few minutes (eggs), up to twenty hours (adult). If the Chao has enjoyed life, it will enter a pink cocoon and reincarnate. An egg will then be left so that Chao can enjoy life another time. In most cases *Coupled Games* are Asynchronous Games and "actions that take place in one game become Trans-game Information in the other" (Davidsson et al., 2004, p.16).

With the pattern *Coupled Games* we investigate one mechanism of pervasive mobile learning games. In the context of our research the coupling comprises two components: short messaging services (SMS) notifications that we designed as a quiz and a PC-based Browser Game.

In order to assess the educational effects of the pattern *Coupled Games* for learners at-risk, this chapter firstly provides an overview of related work on the use of SMS for education. Subsequently it outlines the educational intervention and technical infrastructure of the game. The chapter then describes the methodology of the study and depicts how the characteristics of the target group have informed the game design and the methodological approach of the study. It concludes by presenting data from an empirical study that investigated the learning outcomes for learners at-risk and eventually discusses resulting implications for future design decisions based on the pattern *Coupled Games*.

5.2 Related Work

In our approach to pervasive games for learning we use SMS as a game element that pushes the boundaries of the coupled Browser Game. Before outlining the educational intervention, we present a representative selection of studies on the use of SMS notifications for educational purposes, followed by a discussion of their shortcomings and restrictions.

Text messaging has become the dominant mode of electronic communication amongst young adults and plays a central role in maintaining their social networks (Harley et al., 2007; Porath, 2011; Markett et al., 2006). Building on this evidence, practitioners and academics are looking at the design and impact of SMS for teaching and learning (Ziden and Rahman, 2013; Brett, 2011; Lim et al., 2011; Santos, 2010). Even though using SMS technology is a comparatively old concept, research into this field states that students' familiarity with this type of conversation (Attewell, 2005), the minimal disruption it causes (Horstmanshof, 2004), the potential of SMS for interactivity or the low-threshold access it provides with regard to learning and technology (Markett et al., 2006; Kim et al., 2006) make it favorable for use in an educational context.

The study by Santos (2010) showed that using SMS in the classroom encourages students' further thinking and exploration of course topics outside class time and Cavus and Ibrahim (2009) report that using SMS effectively supports students' learning of new technical English language words. Attewell and Savill-Smith (2004) argue that SMS provide low-threshold learning opportunities and, instead of inhibiting the learning of spelling and grammar as frequently suggested, contribute to improving young people's literacy (p.5). Harley et al. (2007) stress that text messages facilitate the development of productive relationships for those who would otherwise be socially isolated. A study on the impact of SMS on students' self-regulated learning strategies argues along these lines. It suggests using the principles of persuasive technology for sending SMS messages especially for the high risk students (Goh et al., 2011). The study shows that students who received persuasive SMS intervention performed better than students who did not receive any SMS intervention. Additionally, the study demonstrates the positive impact of persuasive SMS on students' learning and suggests that the intervention can improve students' self-regulated learning effort. Crabtree et al. (2007), in their report on the mobile game "Day Of The Figurines", have evaluated the potential of a game that exploits SMS as a primary means of interaction. Their findings indicate that the success of the game relies on the "orchestration of messaging by behind the scenes staff" (p.42). This, for example, includes "categorizing messages so that appropriate next actions can be taken, which relies on interpretive work to make sense of messages" (p.42) or "crafting responses to engage players in the game" (p.43).

When using SMS in class, concerns with regard to costs for receiving and sending out SMS, learner focus and attention or intrusion into personal time have to be well considered (Brett, 2011). However, they should not hinder the use of SMS in the classroom. "A pedagogically supported use of SMS within classrooms may allow for low-cost implementation of real-time, text-based interactions and put an end to the familiar refrain of "turn UR mobiles off" (Markett et al., 2006).

Despite the use of SMS in class being reported as effective, little is known about what makes their use successful in an educational role. The paper by Yengin et al. (2011) provides a detailed analysis of the technology used for SMS and gives examples of different research studies of successful implementations in education, but gives no explanation for the stated success by deducing guidelines, for example. However, the paper by Wang et al. (2008) does propose guidelines. Based on a review of tools used to design mobile media, e.g. the use of audio, captions or icons, they set up message design principles for mobile learning that consider learning theories and instructional design principles. Still, with regard to the benefits and drawbacks of text messaging as an accepted educational tool, further research is needed that evaluates the role of text messaging or the impact of long-tern use on youth literacies (Porath, 2011).

Based on this evidence, our research explores how SMS, employed to realize the pattern *Coupled Games*, may support learners at-risk. Our scenario uses SMS interventions in the form of a mobile learning quiz. The quiz is coupled with a PC-based learning game to evaluate how the pattern *Coupled Games* impacts students' motivation and learning outcomes. A similar approach has been adopted by Attewell (2005). Her study employed SMS as an entertaining addition to classroom lessons. Study results emphasize the relevance of mobile learning for at-risk learners, attracting young people to learning and supporting their learning and development. Mobile learning takes away some of the formality from the learning experience and engages reluctant learners. Beyond that, the use of mobile devices may counteract resistance to the use of ICT thus bridging the gap between mobile phone literacy and ICT literacy. In the following we describe how we realized mobile learning in the context of an educational game that aims at improving ICT literacy for learners at-risk and outline the technical infrastructure.

5.3 The Coupled Game Intervention

5.3.1 Instructional Approach

The underlying pattern for the study is the pattern *Coupled Games*. We employed this pattern by coupling a mobile game extension to the Multiplayer Browser Game *BauBoss* (Schmitz and Czauderna, 2011). *BauBoss* (see Figure 3.1) was introduced to foster the acquisition of skills and abilities of at-risk learners in using commonly used application software, i.e. Office (Schmitz and Czauderna, 2011). It is based on the assumption that when games appeal to students, playing them will enhance their intrinsic motivation to learn and will improve learning (Charsky and Ressler, 2011). Czauderna and Erlenbusch (2012) in their study assessed and partially corroborated this. The experimental setting of their study comprised five, moderated gaming sessions. Each session lasted between 60 and 70 min. After each session, participants were asked to carry on playing at home. Our study was part of this evaluation.

The main intention of *BauBoss* is to bring at-risk learners "in touch" with IT content. Therefore, applying IT knowledge by answering questions from the European Computer Driving License (ECDL), which the game offers, is a vital way to score (Schmitz and Czauderna, 2011). The ECDL is a standardized test that reflects and certifies up-to-date skills and knowledge in computer use and common software applications. The questions are introduced by way of a ringing telephone, which the player can choose to answer or reject. Questions answered correctly have an in-game advantage, i.e. they increase the IT-Checker value (an expertise score) and a high IT-Checker value shortens the time to finish buildings. The quicker a building is finished, the quicker the player can generate money from letting it. This again influences the money index and respectively the score increases. To integrate the question more seamlessly, the player is asked to help a colleague (site foreman) who needs to send a construction plan for instance and requires help with regard to the most appropriate data format.

This mechanism was kept for our SMS-based game extension of the learning game. The mobile game extension was defined as an additional set of SMS notifications to the Browser Game *BauBoss* by way of multiple- and single-choice questions (SMS quiz). They were introduced as a request for help. The questions had to be answered quickly because only the first two participants who sent correct answers received the bonus, which subsequently added to the IT checker value (Schmitz and Czauderna, 2011) of the coupled Browser Game.

Table 5.1 Text messages sent to the experimental group

Kind of SMS posted to the experimental group	Number of messages (N = 180)
Multiple choice questions (quiz)	70
Information on the IT content	60
Hint as to the performance of others	50

We sent three messages per week outside class time (see Table 5.1), i.e. before the sessions, for lunch break, or in the afternoon: (a) multiple- and single-choice questions (quiz) relating to the *BauBoss* game, (b) hints referring to IT-related subjects , and (c) hints containing information such as notification of friends' scores, for example: *"The cities of your friends have become prosperous. By enlarging your IT knowledge, you can quickly catch up"*. The hints referring to IT-related subjects were sent once a week (usually Fridays). With the knowledge notifications we meant to support general interest in IT and to refresh the content already learned. (See Appendix B for the list of message we sent and their sequential order.)

The quiz questions were sent out two to three days later (usually Mondays). We provided instant feedback on the questions. The correct answer was provided in the case of both correct and incorrect replies. With this, further chunks of information were sent to the participants. In the early morning before the Browser Game phase (usually Wednesdays), we sent hints containing information on friends' scores. With this notification we aimed at supporting interest in the *BauBoss* game. Monitoring and coordinating gameplay "from behind the scenes" has proved vital for players' gaming experience (Crabtree et al., 2007).

For the formulation of the SMS notifications we took into consideration the target group's literacy skills, e.g. we paid heed that the text be as short and clear as possible. Also, the messages were aligned to the target group's restricted attention span, i.e. multiple-choice questions with a choice of only four answers, and a maximum of approximately 50 words per message. We designed the SMS-based content that could be used on different devices and that was based on the type and the activities participants' devices could support (Wang and Shen, 2012). In order to be able to do so we asked teachers to interview participants in advance with regard to the devices at hand (smartphones/mobiles/iPhones). The responses were received anonymously. We used the "captioned content" (Wang and Shen, 2012), which can significantly improve reading comprehension, word recognition or decoding skills and provides "the flexibility that is essential for mobile messages to be received in a variety of changing contexts" (Wang and Shen, 2012, p.572). Mainly, this was important because we sent out the SMS messages in the afternoon and participants received these messages on their private mobile phones.

5.3.2 Technical Infrastructure

From a technical point of view, the starting base and corresponding requirements for the experiment were very diverse. Ten out of 18 learners owned smartphones. The ten smartphones were equipped with four different operating systems (5 Symbian, 3 Android, 1 Bada, 1 iOS). Eight participants owned a conventional mobile phone. Purchasing smartphones for the experiment was not mandated. Thus, the prototype *WeBuild* that was initially developed to evaluate the impact of coupled games (Schmitz et al., 2012a), we were not able to use. The devices would have had to be loaned by the instructor who would have been liable for theft and loss of class time. This led to the decision to settle on conventional mobile devices as a "common denominator" and on the use of text messaging via SMS, a service which is available on all mobile phones. This way, all learners were able to participate by using their own devices for the game. On the other hand, participants had to pay network charges for sending the messages, which is a potential drawback (Cheung, 2008). We addressed this problem by offering a cash rebate for the messages sent.

The stream of activity was designed through an SMS voting system (http://www.openit.de/sms-einsatz.html), which we describe in Figure 5.1. Technically, an integration of the mobile quiz game into the Browser Game *BauBoss* was possible and thus considered but due to interfering project tasks postponed. However, the decision to use an SMS voting system had little bearing on the game design. The intended coupling of mobile quiz game and Browser Game via the IT-checker value was still possible.

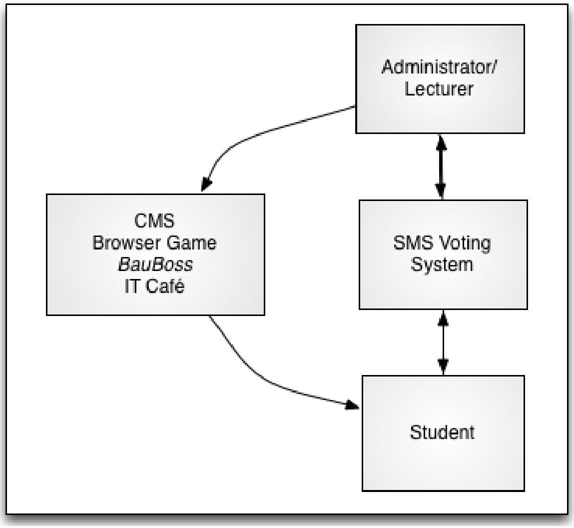

Figure 5.1 Activity stream *Coupled Game*

Through a number provided by the system we sent out messages and participants replied to the designated phone number. This way we were able to receive participants' answers in real time (live voting) and, at the same time, to collect the responses electronically for efficient data processing. The system sorted all incoming SMS according to date, time, telephone number, and text (content). The incoming quiz results were evaluated and through the browser-based game *BauBoss* students received their feedback by way of an increase of their IT Checker value. In addition, the system made it possible to group participants according to certain parameters such as the message content, class, etc., which enabled us to customize text messages according to different categories of learners and to organize messages beforehand.

5.4 Method

Mobile learning games provide low-threshold learning opportunities that enable the development and improvement of confidence, autonomy, and engagement (Traxler, 2010; Douch et al., 2010). Also, the use of SMS for learning has been found to enable low-threshold learning opportunities that support learning (Attewell and Savill-Smith, 2004; Goh et al., 2011). However, little is known about how mobile learning by way of games and SMS actually influence learning. Our research aims at contributing to research in the field. By combining mobile game-based learning and SMS messages its main objective is to understanding how the pattern *Coupled Games* influences both information access and motivation for at-risk learners.

We thus formulated the following two hypotheses:

H1: Participants receiving SMS interventions will show higher motivation to deal with the IT content in general and software applications in particular than those playing the PC-based version of the game BauBoss.

H2: Participants receiving SMS interventions will perform better (higher knowledge gain) than the pupils playing the PC-based version of the game BauBoss (no mobile intervention).

5.4.1 Participants

We carried out the experiment in spring 2012 (January - March). A total of 19 learners from state-funded professional qualification programs offered by the Education Centers for the Building Industry (Bildungszentren des Baugewerbes e.V.) aged from 16 to 21 years participated in the study for seven weeks. The target group consisted of male participants only. From various points of view, this is a very challenging task. For one, the target group cannot easily be described as homogeneous. The 19 participants had very different (and partly very difficult) learning histories as well as diverse social backgrounds and cognitive capacities. Only a few of them had a school-leaving certificate. In general, the target group is difficult to motivate. Their low self-esteem, low frustration tolerance and poor stamina leads to high drop-out rates. Most participants frequently use mobile devices, but mainly for communication (texting messages, calling friends).

For the intervention, participants were randomly assigned to one of two groups, experimental group ($n = 10$) and control group ($n = 9$). During the sessions, both groups played the Multiplayer Browser Game *BauBoss*. After the session, both groups were asked to carry on playing at home. The experimental group additionally dealt with the mobile learning game (coupled game which comprised Browser Game and SMS interventions). The control group dealt with the PC-based version of the game only.

5.4.2 Measures

Data were collected through questionnaires and interviews. To capture the information on both motivation and knowledge gain, we mixed (a) qualitative data such as open-ended and bounded questions with (b) quantitative data coming from a standardized test and event log files generated automatically by the game.

Motivation to deal with learning content. This measure contained a post-game qualitative questionnaire with 15 questions loosely based on a combination of already existing questionnaires to measure player engagement (Francis, 1993; Malone, 1980) and an interview. The 15 items from the questionnaire were arranged for scoring on a five-point Likert scale, ranging from "agree strongly", through "agree", "not certain" and "disagree", to "disagree strongly". For average and standard deviation calculations we assigned value SA as five points, A as four points, NC as three points, D as two points and SD as one point. We evaluated participants' response to the game and the corresponding SMS interventions. The questionnaire included bounded questions designed to obtain feedback on engagement, attitude toward IT learning, game play, group and game experience.

Knowledge gain. Due to the rather heterogeneous group of learners we used a pre- and a post-test to measure the learning effects of the intervention. Both tests comprised the same set of 80 IT test items. In order to ensure a mapping of results we used key numbers for the participants. The test was adapted from the ECDL and administered under the supervision of teachers and two investigators.

Attraction to gameplay. We analyzed data from learner tracking to further disclose the acceptance of the application and its actual usage. These log-data comprised log in-times, handling of IT questions within the game, use of networks and chat, etc. They complement the qualitative and quantitative results and document the real user data. Both the data from learner tracking and from the IT knowledge test we could trace back to individual participants due to a coherent use of key numbers. In addition, we added data from learner tracking. These data comprise log-in times, handling of IT questions, use of networks and chat, etc. They complement the qualitative and quantitative results and document the real user data. Both the data from learner tracking and from the ECDL test could be traced back to individual participants due to a coherent use of key numbers.

5.5 Findings

In the following we present the results from our study. The experimental setting comprised five, moderated gaming sessions. Each session lasted between 60 and 70 minutes.

5.5.1 Quantitative Feedback

For motivational aspects, we analyzed participants responses to a questionnaire. From a total of 19 participants, five did not manage to complete the questionnaire. As a result, 6 students remained in the control group while 8 students remained in the experiment group.

Hypothesis 1. Participants receiving SMS interventions will show greater motivation to deal with the IT content in general and software applications in particular than those playing the PC-based version of the game BauBoss.

Table 5.2 compares the control and experiment groups' motivation to deal with the IT content in general and software applications. The mean opinion scores and standard deviations of students' survey responses are given in Table 5.2 and 5.3. At a glance, the results suggest that students from both the experimental and the control group shared the same viewpoint upon this issue. However, with regard to question items 2, 4, 5 and 10 there were differences. These items took the use of computers for work into consideration.

Table 5.2 Comparing the control and experiment groups' motivation to deal with the IT content in general and software applications.

	Statement	Experimental group n=8 *M (SD)*	Control group n=6 *M (SD)*
1.	Learning about IT is interesting.	3.875 (0.781)	3.333 (1.106)
2.	I frequently use the computer to work.	3.625 (1.251)	2.333 (1.247)
3.	I am not the type to do well with computers.	2.625 (0.893)	2.333 (0.953)
4.	Learning about IT is important for my job.	3.625 (0.857)	2.833 (0.687)
5.	Computers and IT are boring.	1.750 (0.661)	2.500 (1.500)
9.	Learning about IT is interesting	2.625 (1.386)	2.667 (1.054)
10.	Learning about IT helps me on my job.	3.500 (1)	2.667 (0.745)

As for question item 2 the mean value of the responses for the experimental group was 3.625 (SD = 1.251), control group 2.333 (SD = 1.247) and for question item 4 the mean value of the responses for the experimental group was 3.625 (SD = 0.857), control group 2.833 (SD = 0.687). Furthermore, question item 5 reveals that the experimental group tends towards liking the topic. The experimental group (M = 1.75, SD = 0.661) did not find the topic as boring as the control group (M = 2.5, SD = 1.5).

Table 5.3 shows that in the dimension of looking at the IT content in the IT-Cafe, a difference of average score for experimental group and control group is recognizable (experimental group M = 3.5, SD = 0.707; experimental group M = 2.167, SD = 0.898). Participants from the experimental group rather used the IT-Cafe to look up the content and thus to better play the game.

Table 5.3 Comparing the control and experiment groups' motivation to deal with IT content in the game

	Statement	Experimental group *n*=8 *M (SD)*	Control group *n*=6 *M (SD)*
6.	Learning games are great to learn about IT.	4.125 (0.111)	3.833 (0.373)
11.	I looked at the IT content in the IT-Cafe and used it for the game.	3.500 (0.707)	2.167 (0.898)
12.	I have answered the questions in the game with the help of my friends.	1.750 (0.433)	1.667 (0.623)

In the dimension of collaboration (question item 12), the average score for both groups is comparable with the score of M = 1.75 (experimental group) andM = 1.667 (control group) and the standard deviation of 0.433 and 0.623 respectively, which indicates that participants shared the same view point upon this issue, i.e. they answered the questions on their own.

Hypothesis 2. Participants receiving SMS interventions will perform better (higher knowledge gain) than the pupils playing the PC-based version of the game BauBoss (no mobile intervention).

Table 5.4 is based on six responses from the experimental group and six responses from the control group for both the ECDL pre- and post-test. One student who only participated in the pre-test was beforehand omitted from the data. The pre-test was conducted before the first game session in January 2012 and the post-test after the last game session in March 2012.

Table 5.4 Results from the IT testing

	Pre-test *n* = 6		Post test *n* = 6	
	M (SD)	*Mdn*	*M (SD)*	*Mdn*
Mobile intervention (experimental group)	63.83 (10.221)	65	69.33 (8.380)	70
No mobile intervention (control group)	62.83 (11.495)	64	65.5 (13.238)	65

Results from the IT testing indicate that participants from the experimental group attained higher scores on the pre-test (experimental group M = 63.83, SD = 10.221; control group M = 62.83, SD = 11.495). However, in the beginning both groups already had different previous knowledge. This makes an evaluation of the impact of coupled games on knowledge gain difficult. However, the results given in Table 5.4 show that participants who played the mobile learning game attained higher scores on the knowledge post-test with smaller standard deviations (experimental group M = 69.33, SD = 8.38; control group M = 65.5, SD = 13.238). This effect also applies to the variation of standard deviation for the experimental groups' pre- and post-test (pre SD = 10.221, post SD = 8.38). Thus, from the IT testing a clear effect of the intervention (playing the mobile learning game) showed for the experimental group.

5.5.2 Log data analysis

In order to evaluate whether the SMS interventions were a stimulus for the target group to play the game, we analyzed the log data. We considered ten datasets available for players of the experimental group and seven datasets from players of the control group. The number of active sessions was ascertained by the pairs of log-in/log-out data and activities immediately after the log-in. Table 5.5 sums up the results.

Table 5.5 Descriptive statistics from log data analysis

	Experimental Group n = 10		Control Group n = 7	
	M (SD)	Mdn	M (SD)	Mdn
Time spent within the application (min.)	273.6 (131.725)	272	187.14 (132.665)	196
Number of active sessions (log-ins)	11.6 (9.371)	7	6.42 (4.894)	7
Duration of active sessions (min.)	23.58 (22.614)	13	29.11 (21.729)	30
Number of IT questions answered	62 (29.051)	51.5	59.57 (42.902)	61
Number of questions answered correctly	37.9 (20.994)	33.5	39.14 (27.064)	42

The log data analysis revealed that participants from the experimental group spent an average time of 273.6 minutes on the application (SD = 131.725; control group = 187.14 minutes, SD = 132.665). For an individual session, participants from the experimental group spent an average time of 23.58 minutes on the application (SD = 22.614; control group = 29.11 minutes, SD = 21.729). Though, for participants from the control group an individual session took longer, participants from the experimental group had more active sessions on average (experimental group M = 11.6, SD = 9.371; control group M = 6.42, SD = 4.894). Participants from the experimental group answered an average of 62 questions (SD = 29.051; control group M = 59.57, SD = 42.902). On the other hand, participants from the control group answered more questions within the game *BauBoss* correctly (control group M = 39.14, SD = 27.064; experimental group M = 37.90, SD = 20.994). Also, from the log data it showed, that participants from the experimental group frequently accessed the application whenever they received a message and in particular when receiving a personalized massage.

5.5.3 Student feedback to the SMS interventions

When comparing the results from the usage data of the application to the student feedback, a similar picture shows. Participants from the experimental group demonstrated a rather reluctant attitude towards the use of text messages. It showed that simply sending messages is not necessarily attractive to them and does not thrill them to make use of the learning offer provided. To them, *BauBoss* belonged to schooling activities and thus had no relevance to their everyday life. One participant remarked,
P1: [...] *and the SMSs come in situations when I do not expect it and this could really annoy me.*

After a while however, some started to accept the intervention. One participant explained,
P2: *"No, in the beginning I thought, this is pretty annoying. But after a while, got the SMS, talked with friends. Because most of the time we are all out together. And then, 'Ah, I got an SMS from BauBoss.' 'Yes, then I will get one too, for sure.' Then we answered the question together"*.

P3: *Not bad. When you are out, as a reminder. You are still playing BauBoss, getting an SMS, you can simply and instantly play the game a little, it was actually not bad"*.

Conversely, three participants expressed dislike for the quiz messages. When questioned why, they brought forward the argument of extra costs. They obviously were frequently expected despite the fact that it was made clear beforehand that any costs would be refunded. One participant did not state a clear reason (e.g. money, lack of knowledge) for not responding to the SMS questions.

Interviewer (I): *There were SMSs sent to you. Did you receive them?*
P4: I got them.
I: Did you reply to them or did you find this ...
P4: No, I haven't
I: ... yes. Why haven't you answered them? [...]
P4: Actually I did not want to. There was another number and I have E-Plus, and you then have to pay for it.

Another student argued similarly: I: *[...] Did you receive SMSs?*
P5: Yes, but I did not answer.
I: How many?

P5: Yes, got many, yes.
I: How many?
P5: Yes.
I: Did you reply to none of them? Not at all?
P5: No.
I: Why not?
P5: I have a different provider. It will be very expensive for me.
I: That was the only reason?
P5: Yes

Most participants valued the collaborative and social dynamics of the game:
P3: *When the SMS came. Yes, some said, BauBoss again, and I have, and others have then (said) 'Oh BauBoss!'. And we then discussed, yes once we even sat together with some people and an SMSs came, from the BauBoss again and (we) then really fiddled and thought about it the whole time, what is it again? And then I said 'Well boys, you have to boost the IT-Checker.' And then I answered the question and that was it*.

5.6 Limitations of the study

The current study has certain limitations that need to be taken into account. Due to the high dropout rate, a regular problem when working with the target group, our test audience was rather small, which makes it difficult to draw broad generalizations from the data. Also, only males play-tested the game. In order to corroborate effects that show in our study, large-scale testing is necessary that additionally takes gender into consideration. Still, we may draw conclusions from the experiments with regard to the design of Couple Games and the use of SMS messages for the target group.

When interpreting the results we have to consider whether the results can be attributed at least partially to short-term effects of novelty. Participants dealt with a teaching method that was new to them. Though they are used to dealing with mobile devices on a day-to-day bases, using the mobile device for learning was new to them. It is thus arguable that with regard to the experimental group, participants' perception and attitude towards learning and IT content changed due to an alteration in their learning environment. Also, factors that may influence participants' perceptions, such as their ability, prior experience with technology, prior background to mobile learning games, and personality type were not considered. However, we assume that our educational study does not suffer badly from this argument because we compared a variation within a learning environment that was new to both groups alike (the Browser Game *BauBoss*). Also, the technology we used (SMS messages) was not a thrilling novelty. Learners are frequently dealing with it. Still, teaching changed and learning implied technology that is unusual within traditional school settings and culture (Price, 2007). Long-term studies are thus necessary to assess whether effects change during repeated use and over time.

5.7 Discussion

Our study demonstrated how mobile games can be employed for educational settings by example of coupled games. This pattern allowed us to use the potentials of mobile phones in a very targeted manner, both as an extension to an existing learning game and as a channel for information. Despite the relatively small sample size we may draw conclusions from our experiment with regard to the use of SMS messages for the target group.

Results showed a tendency with regard to affective and cognitive learning outcomes. Participants from the experimental group showed a more positive attitude toward the subject. Also, learners who played the mobile learning game had a higher knowledge gain. It can be argued that evidence for possible cognitive learning outcome was based on the higher number of questions and information, i.e. the experimental group had more opportunities to learn. With regard to the total number of obligatory questions this is correct. But besides this, every learner had access to all questions at any time. They were accessible via the IT Cafe. This way, every learner had the same opportunities to learn. In our opinion, the important aspect was the fact that participants accepted the input and dealt with the corresponding IT-content, which eventually led to a higher knowledge gain. This was a valuable aspect with regard to the target group. In addition, as backed up by the learners' statements, the educational intervention triggered social dynamics and collaboration amongst learners, which was a valuable aspect with regard to the target group too.

The study emphasized the relevance of mobile SMS for young male at-risk. We expected that the positive effects do not decrease after one use but assume that participants would still be interested in the approach and likely have more information gain. The use of SMS seemingly caused a change for the target group and helped them learning, which was a vital result because motivating at at-risk learners and supporting their learning was both a challenging and vital task. Mobile game-based learning approaches are regarded as powerful tools to back efforts in that direction. They are interactive thus promoting an active learning environment and facilitate the building of learning communities (Markett et al., 2006).

With regard to patterns, the experiment was designed as *Coupled Games*. Other patterns were not explicitly part of the initial mobile learning game design. However, we are aware that related research has argued that game design patterns should not exist alone and that choosing one game design pattern almost automatically requires the presence of other game design patterns (Kelle et al., 2011). As for our experimental setting, the aspect of collaboration for example was a result of the pattern in use. Students stated that they collaborated in order to answer the quiz questions correctly (see participants' statement P3). However, we did not make explicit use of this pattern when designing the game play. With the given technical set-up, there was no actual collaboration possible and implemented on the basic level of SMS quiz. The system we chose enabled sending SMS from the system to the user and reverse. In order to diminish possible drawbacks due to network charges for users, we offered a cash rebate. Further research on notifications systems, such as the approach by Chiu et al. (2007) however, has considered amplified systems that interact with users, providing real-time notifications with multimedia message formats for example. Such a set-up will be considered for further research.

Despite the target group being very attracted to communicating via SMS, our assumptions for the game play have not comprehensively proved right. Feedback from the interviews showed that simply sending messages was not necessarily attractive to them and did not thrill them to make use of the learning offer provided. Firstly, the fear of extra costs. Participants avoided replying to the questions because they expected extra costs despite it was made clear beforehand that any costs will be refunded (see participant's statement P4 and P5). Secondly, the timing of the messages. One participant stated that he was annoyed by the SMS questions as he had received the messages at times when he did not expect them (outside the sessions in the afternoon, esp. during lunch time). Carefully selecting the time when sending the messages is a crucial aspect for the design of a pervasive learning experience. The aspect of anytime, anywhere as a core characteristic of such learning arrangements was not fully appreciated by participants of the target group. The findings are supported by other research such as the study by Holley et al. (2012) and Laine et al. (2010). They, too, stated that the flexibility of pervasive systems to be used anywhere, anytime, and by anyone, can be problematic. Besides the time when sending the messages the actual graphical design of the mobile game surely affected the acceptance and the effects of its use. The target groups' low frustration tolerance reflected in their low willingness to tolerate prototypical graphical user interfaces (GUI), for example. We assume that a state-of-the art mobile game with an appealing graphic interface is more likely to attract their attention and thus their willingness to play the game. This conclusion is fortified by current research (Schmitz et al., 2012a). Though the growing pedagogic and technological sophistication of mobile learning pilots is evident, increased and sustained deployment of mobile learning will depend on the quality of analysis and evaluation of these pilots and trials (Traxler and Dearden, 2005). Thus, future research needs to address the importance of the GUI on motivational and learning aspects as well as different game scenarios. Still, the mobile learning intervention showed positive effects.

5.8 Conclusion

This chapter's contribution to research in the field is based on three pillars. First, we provided an overview of the use of SMS for education. We have reflected on a concise and effective use of the pattern *Coupled Games* and mobile game-based learning in education. Our intention was to enhance insight into the motivational and learning effects of such environments from a pattern design perspective by focusing on the coupled games and the use of text messaging. Second, we exemplary described a low-threshold mobile game scenario that coupled SMS messages with an existing Browser Game. With the coupling, this study presented a multifaceted learning environment that was able to cope with current problems in learner motivation. Third, we presented the results from a study that assessed the impact of the pattern *Coupled Games* on at-risk learners with regard to motivation and knowledge gain. From the study it showed that coupled games have positive effects on students' learning and suggested that the intervention was able to improve students' interest in dealing with the topic. However, further research is needed to comprehensively evaluate the potential and effect of this pattern, in isolation and in combination with other patterns.

Chapter 6

Putting Yourself in Someone Else's Shoes: the impact of a location-based, collaborative roleplaying game on behaviour

The second empirical study focuses on a game that employs the patterns *Physical Navigation, Collaborative Actions* and *Roleplaying*. Employing these patterns enabled the design of an emergency scenario to teach children how to react in case of sudden cardiac arrest. The goal of this study was to probe the effectiveness of a mobile game-based learning approach in modifying behavioural outcomes and competence. It showed that pupils who participated in the emergency scenario held a stronger belief that they could provide CPR in case of emergency and they rather predicted that they would do so in case of emergency.

This chapter is based on: Schmitz, B., Schuffelen, P., Kreijns, K., Klemke, R., and Specht, M. (Manuscript submitted for publication). *Putting Yourself in Someone Else's Shoes: the impact of a location-based, collaborative roleplaying game on behaviour*.

6.1 Introduction

In Europe, approximately 350,000 people die each year due to out-of-hospital cardiac arrest (OOH-CA). On a daily basis, this is around the equivalent of two full jumbo jets, which puts this cause of death in third place behind all cancers combined and other cardiovascular causes (ESA, 2014). Around 100,000 of these deaths could be prevented if members of the public, beginning with schoolchildren, had the resuscitation knowledge needed to save a life. Despite an extensive introduction of cardiopulmonary resuscitation (CPR) training measures in the 1960s, the rate of laymen providing CPR during cardiac arrests is still low (Plant and Taylor, 2012; Vaillancourt et al., 2008a). It seems that knowledge on how to provide CPR is not the only decisive factor. Studies investigating the impact of psychosocial factors on lay-men providing CPR identified factors such as perceived risk of infection with a communicable disease during CPR, or disagreeable physical characteristics, e.g. the presence of blood, which influenced and even prevented lay helpers' willingness to provide CPR (Cho et al., 2010; Coons and Guy, 2009; Johnston et al., 2003; Kanstad et al., 2011; Query, 2006).

Coons and Guy (2009) concluded, "the relative importance of the reasons for not performing CPR is informative" [p. 334]. They emphasized that there is potential to change CPR-related attitudes and beliefs and proposed different forms of educational intervention to achieve this. Axelsson et al. (2000) also argued that CPR trainings should include appropriate models to produce the feelings of personal responsibility and courage required to intervene and to prepare lay helpers emotionally for dealing with unexpected and unwanted situations.

With this chapter we argue that a location-based, collaborative roleplaying game, which simulates an emergency situation, is likely to enable such models. The study by Baranowski et al. (2008) supports this. Their results on the outcomes of video games for children and adults showed that the use of video-game-based intervention promoted changes in attitude and behaviour, which were corroborated by other studies (Peng and Liu, 2008; Plant and Taylor, 2012). Especially the use of CBT, "virtual worlds" and "multiplayer online simulation" in CPR training could be an attractive CPR, AED (automated external defibrillator) and first aid training and/or retention tool to use with children (Pavey et al., 2012).

Building on this strand of research we developed the mobile game environment *HeartRun*. The game supports the efforts of the project EMuRgency (Kalz et al., 2013a), which aims at increasing the number of lay helpers in the long run by providing mass training events for school children. *HeartRun* is a location-based, collaborative roleplaying game that simulates an emergency thus preparing learners to react quickly and adequately in a closely related situation. During cardiac arrests it is important to intervene immediately to save seconds and minutes, and to give the most appropriate help possible. Comparable to an unexpected emergency, the game intervention involves instant decisions on what to do and the recall of CPR knowledge under unexpected circumstances.

This study focused on the interrelation of factors that come along with the use of technology in education. We investigated the potential of a location-based, collaborative roleplaying game that includes the mobile game design patterns 1) *Physical Navigation*, 2) *Collaborative Actions* and 3) *Roleplaying* as described by Davidsson et al. (2004) and contrasted this approach to a more information-based oriented scenario that does not make use of these patterns. The group of patterns has shown to be effective and facilitated the integration of features frequently associated with mobile games, i.e. cooperative action between team players who have different tasks or roles and time-critical orientation in physical space (Blum et al., 2012). Also, this is in accordance with game-design principles, which favour using groups of patterns, as learners seldom perceive a single pattern as a game (Björk and Holopainen, 2004; Kelle et al., 2011).

By focusing on design patterns for mobile learning games we further moulded our ongoing research into game design patterns, which aim at supporting instructional design processes. Little evidence exists to guide this process and to offer any guarantee that the use of gaming principles will be relevant for educational objectives. Thus we focused our research on the following two questions:

RQ1: Does playing a location-based, collaborative roleplaying game affect behaviour (empathy, attitude, subjective norm and self-efficacy) to a larger extent than learning with an information-based approach?

RQ2: Does playing a location-based, collaborative roleplaying game have a greater impact on CPR competence than an information-based approach?

In order to answer these questions, we formulated a series of hypotheses, which we tested in the course of our study. This chapter reports the results. It is divided into four main sections. First, we provide a summary of related work in the field of digital games for health education. Subsequently, we describe the educational intervention, i.e. the location-based, collaborative roleplaying game. Third, we introduce the hypotheses and describe the methodology that we used to test the hypotheses. In section four we present the findings and discuss them. We conclude by proposing possible implications for game designers, in this way providing orientation for future design decisions.

6.2 Related Work: digital games to change health behaviour

Since the early nineties, experiential learning has raised great interest amongst health-care professionals. Experiential learning is learning through/from experience (Cooper and Libby, 1997). It is characterized by learning through doing, roleplaying and simulation, all elements thus far shown by literature to enhance CPR training (Kidd and Kendall, 2007). As a result, practitioners in the areas of health education and physical education have increasingly started to investigate how digital games can assist their particular goals. Studies within this newly created field of games for health (http://gamesforhealth.org/) have looked at efforts to raise awareness, facilitate empathy, built up knowledge, strengthen motivation of patients to take a specific medication or foster positive health-related behaviours (Gerling et al., 2011; Low et al., 2011; Papastergiou, 2009a; Tüzün, 2007).

Digital games are being increasingly employed in diverse health domains for training purposes, and there is extensive reported research on serious video games for health. Study results indicated that the innovative approaches yield positive health-related changes with respectable examples in the fields of dietary behaviour or motivation for physical exercise, e.g. "exergames" (Lucht et al., 2010; Yang and Foley, 2011). Though this field is still in its infancy (Thompson, 2012), results from recent studies showed evidence of the potential for video games to facilitate behaviour change due to the entertaining and engaging environment they provide and to enhance behaviour-specific knowledge, self-regulatory skill acquisition, and modelling of behaviours and skills (Thompson et al., 2007).

Educational games for health particularly involve roleplaying in their educational setup. In their study on how interactive digital games affect helping behaviours, Peng and Liu (2008) found that interactive games positively influenced participants' willingness to help and that role-taking partially moderated this relationship. The authors stated that during the role-taking process, an individual goes beyond his or her typically egocentric manner of perceiving the world to contemplate a different point of view. Chamberlain and Hazinski (2003), in their article "Education in Resuscitation", stated that "repeated practice in realistic roleplaying scenarios with situations and environments students are most likely to encounter" (p. 2578) could increase confidence and the willingness to respond to an emergency.

To the best knowledge of the authors, up until now there are no mobile simulation games for health or resuscitation training in existence that drew upon these findings. Several game approaches for resuscitation training do exist that directed the user's attention to correct performance of chest compression, correct arm position, and performance of basic life support in general. Empirical results with regard to the behavioural outcomes of game-based CPR instructions are largely missing, however, and need further evaluation (Papastergiou, 2009b). The location-based, collaborative roleplaying game introduced in this chapter builds upon previous research. In the following we outline the main pillars of the game design.

6.3 Educational Intervention

HeartRun extends a classic resuscitation course based on practical demonstrations by health care professionals. It follows the "chain of survival" paradigm, used by the European Resuscitation council (https://www.erc.edu/) and is thus based on an international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science (see Fig. 6.1).

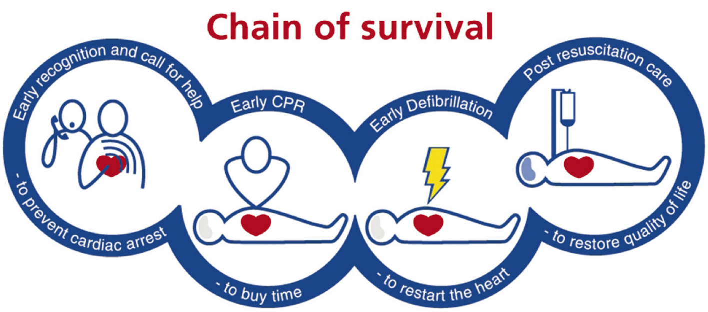

Figure 6.1 Chain of survival for cardiopulmonary resuscitation as described by Nolan et al. (2006).

The sequence of information described above is reflected in the string of message items used for *HeartRun*. We designed two interventions (see Fig. 6.2):

Intervention 1 (I1): A location-based, collaborative roleplaying game simulating a case of emergency.

Intervention 2 (I2): An information-based learning situation.

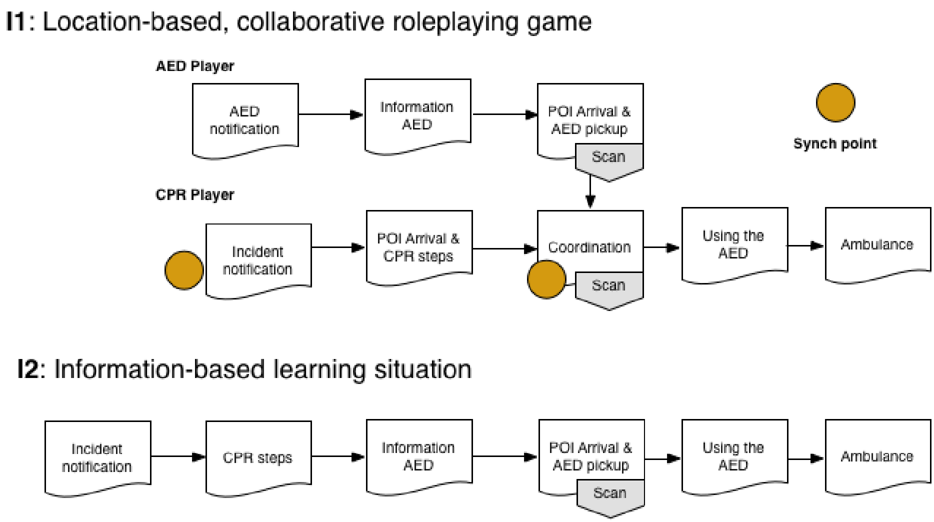

Figure 6.2 Comparison of the two interventions I1 and I2

Intervention 1 provides the opportunity to act out the possible roles involved in a real case of emergency. By "putting oneself into another's shoes, participants have the chance to experience and control both feelings of panic and fear. Students play in teams of two. Every team player is randomly assigned to one of the roles (AED support or CPR). In the course of the game, players get an unexpected alert message (incident notification) that requires immediate action. An agitated caller pleads: *"Quickly, quickly, come to the canteen. George has collapsed. I need your help, please"*. Players then need to take action in order to help.

While Player A (AED support) heads for the AED, player B (CPR) runs to the victim to provide CPR. At the scene of the emergency a manikin is provided with which player B interacts. Meanwhile, player A searches for the nearest AED. As soon as he has found it and scanned the QR code attached to it, the game requires him/her to bring the AED to the victim. At the scene of the emergency player A has to scan another QR code. This synchronizes the players. Henceforth, both players get the same information on how to correctly apply the AED. Both players follow the instructions on the mobile phone's screen and apply the AED to the manikin until the ambulance arrives (last message). Due to restrictions which derived from the school setting (limited access to students due to fixed class schedules or fixed course timing), pupils played *HeartRun* one time.

Intervention 2 is organized as an information-based application and is used by an individual learner. Corresponding to the design of *HeartRun*, it comprises the complete string of information, which is based on the "chain of survival", but does not include the alert message (incident notification). Participants from this group had a mobile phone, too. When opening the first message, players immediately take action: prevent cardiac arrest, buy time, restart the heart, and use the AED.

6.4 Effects of location-based, collaborative roleplaying: Hypotheses

In order to answer the research questions stated above we looked for concepts that describe and explain behaviour generally resulting from an interplay of many variables. The Theory of Planned Behaviour by Ajzen (1991) and related concepts such as the Integrative Model of Behaviour Prediction (IMBP) or the ASE-model are social cognition models commonly capable of predicting and explaining behaviour. They are frequently consulted in different domains and particularly in the field of health education and health care and are well-known theories in CPR research (Dwyer and Williams, 2002; Kreijns et al., 2013; Vaillancourt et al., 2008b). Drawing on this research we formulated a series of hypotheses for our comparative study. It comprised the related factors of self-prediction, attitude, self-efficacy and subjective norm. We further included aspects of empathy and CPR knowledge and competence. All concepts are described in the following.

Predicting of going to help. CPR training aims at increasing the number of lay helpers. If this is effective and translates into actual behaviour, (i.e. whether people who have had CPR training more likely provide it in case of emergency), cannot be measured in the scope of this study because the actual behaviour has not been performed yet. Research in the field of Theory of Planned Behaviour (TPB) and related concepts such as the Integrative Model of Behaviour Prediction (IMBP) or the ASE-model implied that the intention to perform certain behaviour was the most influential predictor for actually showing it. It has been argued in favour of self-prediction as one possible measure for intention or behaviour as self-prediction is likely to include a consideration of those factors which may facilitate or inhibit performance of a behaviour, as well as a consideration of the likely choices of other competing behaviours" (Armitage and Conner, 2001, p. 477). Based on this research we assumed that compared to an information-based learning situation:

H1: Pupils who play a location-based, collaborative roleplaying game will more likely predict helping in case of emergency.

Attitude towards helping. Attitude is an integral component of effective CPR training. The Theory of Planned Behaviour reasons that attitude toward the behaviour as a person's overall evaluation of the behaviour (Ajzen, 2005).

Considerable evidence from field studies and laboratory experiments suggest that roleplaying changes attitudes and, according to the TPB, attitude is a determinant of the intention to perform certain behaviour. We considered the impact of roleplaying on attitude and behaviour and hypothesised that compared to an information-based learning situation:

H2: Playing a location-based, collaborative roleplaying game will result in a more positive attitude among pupils towards helping in case of emergency.

Feeling the urge to socially comply. The concept of subjective norm refers to the pressure a person feels when performing or not performing certain behaviour (Ajzen, 1991). In the context of CPR it reflects the belief s person has that most people who are important to that person may think that he or she should perform CPR in case of an emergency. It comprises the aspect of normative pressure, that is whether one believes their social network wants them to perform the behaviour, i.e. social exert pressure (Ajzen, 2000 cited in Rhodes and Courneya (2003)). We assumed that compared to an information-based learning situation:

H3: Pupils who play a location-based, collaborative roleplaying game will feel more pressure to comply with social influence.

Feeling capable of helping. Self-efficacy is an important factor in many areas of medical education, but has been little studied in resuscitation training, possibly because of the lack of a simple measurement instrument (Turner et al., 2009). Self-efficacy has its origin in social cognitive theory (Bandura, 1998) and is applied to investigate the socio-structural determinants of health as well as the personal determinants. It describes an individual's perceived confidence to perform or not perform certain behaviour (capacity beliefs) and also comprises the individuals' belief in having a choice in the initiation of behaviours (autonomy beliefs).

Even physicians who are competent in performing resuscitation may fail to apply their skills unless they have a strong belief in their own capabilities (Coolen et al., 2010). Also, Leigh (2008) concluded that "by participating in simulation scenarios, students can learn to control feelings of panic and their fear of emergency situations" [and that] "gaining control of these emotions has a positive influence on a student's self-efficacy" (p. 8). We thus hypothesized that compared to an information-based learning situation:

H4: Pupils playing a location-based, collaborative roleplaying game have a stronger belief in their capacity to help.

Feeling for others. Colloquially, empathy is expressed as "putting yourself into another's shoes". Empirical evidence supported the idea that an empathy-evoking experience can bring about greater motivation to help, and therefore may be one method for encouraging sustained motivation to help (Batson et al., 2007; Levy et al., 2002). Pavey et al. (2012), pointed out that role-taking (perspective-taking) is likely to produce empathy, which in turn has been found to be a strong predictor of helping behaviour. We thus assumed that compared to an information-based learning situation:

H5: Playing a location-based, collaborative roleplaying games induces greater concern for another person in distress.

Knowing how to help. An important factor related to CPR intervention is competence. Axelsson et al. (2000), in their study on how bystanders perceived their CPR intervention referred to Kazdin and Bryan (1971). They found that the feeling of competence increased the probability of volunteering to help, and that BLS training increased laypersons' confidence and willingness to perform bystander CPR on a stranger (Cho et al., 2010). Thus, we assumed that compared to an information-based learning situation:

H6: Pupils playing a location-based, collaborative roleplaying game achieve a higher level of CPR knowledge and CPR competence.

In order to test our hypotheses, we conducted an experimental study using the two interventions (I1 and I2) that are based on the mobile simulation game *HeartRun*.

6.5 Method

6.5.1 Participants

A total of 201 participants between 12 and 18 years of age (*M* = 15.11, *SD* = 1.6213) took part in the intervention, 107 females and 94 males. Subjects were from four high schools in Maastricht (*n*=33), Gulpen (*n*=27), Meerssen (*n*=36), Hoensbroek (*n*=72) and one school for vocational education and training in Sittard (*n*=44). We asked pupils whether they would be prepared to participate in a study on mobile applications for CPR training. Those who agreed to participate were randomly assigned to one of the two groups, the experimental group (*n*=129) or the control group (*n*=72). All 201 students, who took part in the intervention from January to May 2014, had passed a resuscitation course four weeks prior to the intervention.

6.5.2 Procedure

To test the impact of the intervention and the hypotheses respectively, we used a post-test control group design. Immediately after the intervention, a 36-item questionnaire of specific and generalized value measured the effects on the concepts hypothesized. Due to a different setting in the CPR training, the group of students in Hoensbroek (n=72) received an extended version of the questionnaire. It comprised an additional set of 12 items to test CPR competence. The questionnaire was translated into Dutch and back into English again in order to avoid biased questionnaire items. The resulting English version is included in Appendix C. An initial draft of the questionnaire was distributed to a group of 8th graders for clarity and acceptability of the items included. A pre-questionnaire was not included. We assumed that a pre-test would reveal the concepts and conceptual interrelations we were about to investigate.

The study presented was conducted as follows: All students were given a verbal introduction to the task and the game, e.g. how to read QR codes with a telephone. Students were told that they would play the game in teams of two. It took them approximately 15 minutes to complete the task and another 15 minutes for them to complete the questionnaire. Due to the small setting (a maximum of four pupils at a time), there were no losses to follow-up. For the intervention, we equipped participants with prepared smart phones. We inserted SIM cards to set up an online connection and installed the application on the device. This way, students only needed to log in via their individual QR code. Players from the experimental group were then randomly assigned to one of the two roles (AED and CPR). After all players logged in they were asked to start the game by tapping on the first message. The researchers' role during the case study was participant observer and intervention was kept to a minimum. As participants were teenagers, identifiable personal information (e.g. user names) was not collected.

6.5.3 Measurement

In order to assess self-prediction, we formulated a hypothetical scenario including information about a situation that is likely to occur. The measure was scored using a 7-point Likert-type scale ranging from 1 (*not at all*) to 7 (*I most certainly would*). For measuring attitude the study adapted items from previous research by Kanstad et al. (2011), Rhodes and Courneya (2003) and Francis et al. (2004). The measures were scored using a 7-point Likert-type scale contrasting *harmful - beneficial, good - bad, worthless - useful and pleasant (for me) - unpleasant (for me).* The items for subjective norm comprise items measuring subjective norm and internal regulation, and were adapted from previous research by Francis et al. (2004) and Rhodes and Courneya (2003). The items for self-efficacy comprise both the capacity and autonomy dimension. The measures were scored using a 7-point Likert-type scale adapted from previous research by Francis et al. (2004) and Rhodes and Courneya (2003) and range from 1 (*strongly disagree*) to 7 (*I strongly agree*). The level of empathy with regard to concern and distress was assessed by adapting the 7-item questionnaire developed by Davis

(1980). Items were scored using a 7-point Likert-type scale ranging from 1 (*not at all*) to 7 (*I most certainly would*. One open response and three single-choice questions with predefined criteria measured the level of CPR knowledge, as was done by medical experts in the context of the EMuRgency project. A 12-item questionnaire assessed the level of CPR competence. Items were scored using a 7-point Likert-type scale ranging from 1 (*never*) to 7 (*frequently*).

6.6 Findings

We used the statistics-programming environment R to analyse quantitative experimental data and answer the research questions. Descriptive statistics were used to calculate subject responses to the questionnaire items. To compare means between the groups we applied the Wilcoxon rank-sum test (Mann-Whitney U test), which is a non-parametric test that has greater efficiency than the t-test on non-normal distributions. It frequently reports the median for each condition, as this statistic is more appropriate than the mean for non-parametric tests. Bivariate correlation was conducted using Spearman's correlation coefficient for non-parametric statistic to examine the effects between self-prediction, CPR competence, attitude, subjective norm, and self-efficacy (capacity beliefs and autonomy).

6.6.1 Behavioural outcomes

Means, SD and median of each of the variables are provided in Table 6.1. Concerning *H1*, which predicted that pupils playing a location-based, collaborative roleplaying game would more likely predict to help in case of emergency, results indicated that there was a significant effect. As shown in Table 6.1, pupils who experienced the game application (*Mdn* = 6.0) predicted at a significantly higher level that they would help in case of emergency than those who dealt with the information-based learning scenario (*Mdn* = 5.0), W = 3754, $p = .021$.

Regarding *H2* it was expected that playing a location-based, collaborative roleplaying game would result in a more positive attitude amongst pupils towards helping in case of emergency. However, results from data analysis were inconclusive. They revealed no statistically significant differences between the two types of learning intervention (location-based collaborative roleplaying scenario versus information-based training scenario) with regard to attitude.

H3 predicted that pupils who experience a location-based, collaborative roleplaying scenario would feel more social pressure to help than pupils learning with the information-based intervention. Again, results from data analysis were inconclusive with regard to

Table 6.1 Comparison of group statistics (mean, standard deviation and median) with regard to behavioural concepts

		Experimental Group (n=129)		Control Group (n=72)		
	Concept	*M (SD)*	*Mdn*	*M (SD)*	*Mdn*	Wilcoxon
H1	Self-prediction	5.36 (1.45)	6.0	4.93 (1.38)	5.00	W = 3754, *p* = .020
H2	Attitude	21.73 (5.09)	23.00	21.03 (4.72)	22.00	W = 4116.5, *p* = .181
H3	Subjective Norm	7.09 (1.92)	7.00	7.29 (1.69)	7.00	W = 5023, *p* = .328
H4	Self-efficacy	24.15 (3.61)	24.00	24.06 (3.95)	24.00	W = 4594.5, *p* = .901
	Capacity beliefs	10.71 (2.44)	11.0	10.00 (2.33)	10.00	W = 3794.5, *p* = .030
	Autonomy	13.39 (2.61)	13.00	13.67 (3.44)	13.00	W = 4397.5, *p* = .531
H5	Distress	24.62 (7.66)	25.00	23.40 (6.35)	23.50	W = 4224.5, *p* = .289
	Concern	34.19 (5.25)	34.00	33.61 (5.32)	34.00	W = 4409.5, *p* = .553

this hypothesis. No significant difference between the two types of intervention showed.

With regard to *H4* it was expected that pupils playing a location-based, collaborative roleplaying game have a stronger belief in their capacity to help. For the overall evaluation of self-efficacy the type of intervention revealed no significant difference. With regard to capacity beliefs, however, pupils in the emergency situation (*Mdn* = 11.0) held a significantly stronger belief in their capability to help in case of emergency than participants from the control group (*Mdn* = 10.00), W = 3794.5, *p* = .030.

H5 predicted that playing a location-based, collaborative roleplaying game induces greater concern persons in distress. Again, data results were inconclusive and revealed no significant differences between the two types of learning intervention for empathy.

6.6.2 Effect on CPR knowledge and CPR competence

H6 predicted that a location-based, collaborative roleplaying experience would produce a higher level of CPR knowledge and CPR competence than the learning situation based on conveyed information. The data revealed no significant difference between the two types of learning intervention for CPR knowledge. As shown in Table 6.2, participants from both groups answered at least two questions correctly and more than half of them answered all questions correctly. Results from the chi-square test for independence algorithm confirmed that the type of learning intervention (location-based collaborative roleplaying scenario versus information-based training scenario) had no significant effect on pupils' CPR knowledge, $\chi^2(2, 201) = 1.94$, $p > 0.380$.

Table 6.3 presents results for the assessment of CPR competence, which we evaluated by the additional 12-item questionnaire with continuous variables that we introduced at

Table 6.2 Comparison of group statistics with regard to CPR knowledge in percentages (total)

	Number of correct answers for CPR knowledge test				
	0	1	2	3	4
Experimental Group (n=129)	-	-	3.10 (4)	29.46 (38)	67.44 (87)
Control Group (n=72)	-	-	5.56 (4)	36.11 (26)	58.33 (42)

the school in Hoensbroek. Recall that participants from both groups, the experimental and the control group, had previously had identical training. Despite this fact, results from data analysis for CPR competence showed a significant difference based on the type of training pupils received, W = 426, *p* =.021. Thus, with regard to CPR competence, which was assessed by the additional set of questionnaire items, results supported *H6*, which predicted that a location-based, collaborative roleplaying experience would produce a higher level of CPR competence than the learning situation based on conveyed information only.

Table 6.3 Comparison of group statistics (mean, standard deviation and median) regarding CPR competence

	Experimental Group (n=129)		Control Group (n=72)		
	M (SD)	*Mdn*	*M (SD)*	*Mdn*	Wilcoxon
CPR Competence	73.68 (11.08)	78.50	69.96 (7.66)	71.00	W = 426, p = .021

For further analysis of the effects of a location-based, collaborative roleplaying game we examined the results with regard to self-prediction by distinguishing two groups: the first group included subjects from the experimental group who indicated that they are likely to give CPR (self-prediction = 5, 6, or 7), and the second group included subjects from the experimental group who indicated that they are un-likely to give CPR (self-prediction = 1, 2, or 3). For the analysis we included the 97 participants from the experimental group who indicated that they are likely to provide CPR in case of emergency and the 13 who indicated that they are unlikely to provide CPR.

Means and standard deviation for each of the variables in the two conditions (unlikely/likely to provide CPR) are provided in Table 6.4. This shows that those who are likely to provide CPR reported a more positive attitude towards helping (W = 409, *p* = .0399) and felt more strongly that they are capable of helping in case of emergency (W = 350, *p* = .009). There was no difference between the variables with regard to subjective norm, self-efficacy autonomy beliefs, concern and distress.

Table 6.4 Descriptive statistics (mean and standard deviation) for each variable in each condition for the experimental group

	Unlikely to help (n = 13)	Likely to help (n = 97)	Wilcoxon
2. Attitude	18.77 (6.56)	22.28 (5.01)	W = 409, *p* = .0399
3. Subjective Norm	7.31 (1.80)	7.06 (1.91)	W = 665.5, *p* = .744
4. Self-efficacy (capacity beliefs)	8.62 (3.38)	11.05 (2.13)	W = 350, *p* = .009
5. Self-efficacy (autonomy)	12.69 (4.46)	13.65 (3.34)	W = 571, *p* = .583
6. Concern	33.08 (5.12)	34.34 (5.38)	W = 568, *p* = .565
7. Distress	24.15 (8.80)	24.07 (7.51)	W = 695.5, *p* = .550

Results from bivariate correlation analysis reflect these findings too (see Table 6.4). Regarding attitude and self-efficacy, a statistically significant relationship is seen between the positive conviction someone holds about helping in case of emergency and his/her attitude towards helping as well as his/her feeling of competence to help. For self-efficacy and distress correlation analysis shows negative correlations between the two variables. Further analysis with a modified questionnaire and different statistical analysis is needed to further investigate this relationship.

Table 6.5 Bivariate correlation matrix for the experimental group

	2	3	4	5	6	7
1. Self Prediction	.26**	.13	.24**	.24**	.12	-.06
2. Attitude	1.00	-.06	.27**	-.08	.15	.06
3. Subjective Norm		1.00	.03	.09	-.09	-.10
4. Self-efficacy (capacity beliefs)			1.00	.33**	.10	-.29**
5. Self-efficacy (autonomy)				1.00	.20*	-.20*
6. Concern					1.00	.25**
7. Distress						1.00

* p < 0.05, ** p < 0.01

6.7 Discussion

The purpose of this study was to assess the potential of a location-based, collaborative roleplaying game in comparison with a more information-based oriented scenario. Based on prior research, a series of variables were chosen and the corresponding hypotheses were tested in order to answer the research questions.

Does playing a location-based, collaborative roleplaying game affect behaviour to a larger extent than learning in an information-based situation?

This was measured using concepts that explain behaviour, and results indicated that the type of learning scenario significantly influences self-prediction. Results suggested that the emotional experience of an emergency simulation as realized by the location-based, collaborative roleplaying game translates to a feeling of self-efficacy that is related to capacity beliefs rather than autonomy. Pupils who participated in the emergency scenario held a stronger belief that they could provide CPR in case of emergency and they tended to predict that they would do so in case of emergency. The type of scenario did not affect the other parameters we assessed.

Does playing a location-based, collaborative roleplaying game have a greater impact on CPR competence than an information-based learning situation?

According to the initial hypothesis, playing a location-based, collaborative roleplaying game should have affected the level of CPR knowledge. However, results were inconclusive regarding the effectiveness of the type of learning scenario and CPR knowledge. Results showed no difference for the original set of four single-choice questions. We assume that the questions were too easy and too few to indicate any differences. With regard to the additional set of 12 questions, which assessed CPR competence by using a 7-point Likert-type scale and which were used with the group of students in Hoensbroek, statistically significant results surfaced. From this we deduce that the type of application, i.e. the patterns *Physical Navigation, Collaborative Actions* and *Roleplaying*, can significantly influence CPR competence.

The varying results may be due to the design of the mobile game-based application itself, which does not contribute to changes in behaviour, or it may be that the actual setting of the gameplay impacted results. For example, we noticed that the age of learners had an effect on their getting involved with the game. It worked better for younger pupils than for older ones. Up until grade eight, it was comparatively easy to get them into the simulation. However, from the age of 15 years onwards it was increasingly difficult for them to engage in the application, especially in public.

Also, the site of the action was important. Playing mobile games differs in many ways from playing games on desktop computers. Regarding their use for learning, this frequently involves exchanging the "safe" learning environment of the classroom for a public setting, for example. When interfacing with a "real" physical environment, aspects such as self-display while learning come into play. This is a hitherto neglected topic in the design of educational games. Environmental aspects need strong consideration in the design of the actual game, however. Future research in mobile game design needs to strongly consider this issue and further investigate on the effects of favourable vs. unfavourable settings for mobile games for learning.

Last but not least, educational background affected results adversely. Although mobile games for learning are often considered a support mechanism particularly for learners who are difficult to reach (Douch et al., 2010; Schmitz et al., 2013b; Traxler, 2010), this target group was actually difficult to involve with the game. The 44 participants from a school for vocational education and training in Sittard, which we included into our study, were even less prepared to act out in public and displayed apparent disinterest in playing the game by not paying attention to the introductory part of the game, for example.

With regard to game design we based our study upon the use of concrete patterns for mobile game design, i.e. *Physical Navigation, Collaborative Actions* and *Roleplaying*. The use of these patterns enabled us to design an emergency scenario that was more effective for pupils. Pupils who participated in the emergency scenario held stronger beliefs that they can provide CPR in case of emergency and they also predicted that they would rather do so in case of emergency. From this we conclude that learning activities that are more embedded in meaningful contexts may change behaviour. This is corroborated by previous research results on mobile game design patterns (Schmitz et al., 2013a). There, evidence was found that the appropriate use of context information has the potential to enable attention, activation or attitude, and can increase the motivational appeal of educational game contents.

However, the use of one pattern mostly requires the presence of another game design patterns, (Björk and Holopainen, 2004). In order to reduce such complexities in the pattern approach, further research on the correlations between patterns and learning outcomes has to focus on a limited number of the patterns in existence (Björk and Holopainen, 2004; Davidsson et al., 2004). In order to identify the impact of individual game patterns, e.g. the aspect of physical navigation, further research is necessary that discriminates the experimental setting by individual patterns.

Further exploration into the potential of these patterns is necessary in order to obtain detailed information on their impact on mediating variables and to better understand the interrelation of factors that play a role for the use of technology in education.

6.8 Conclusion and Future Work

This study illustrated the effects of a location-based, collaborative roleplaying experience as one mechanism of pervasive mobile games for learning. In conclusion, using authentic game scenarios based on the patterns *Physical Navigation, Collaborative Actions* and *Roleplaying* can be successful in training younger school children. Findings suggested that an emergency simulation based on the pattern combination may improve self-prediction and self-efficacy (capacity beliefs) and support CPR competence. Further research is needed to investigate the potential link between the variables involved and using a location-based, collaborative roleplaying game.

As results indicated a possible association between distress and self-efficacy, mediating effects need consideration, e.g. the mediating effect of attitude or self-efficacy between empathy and the prediction to help. One possible pathway is to set up a model that reflects the impact of attitude, subjective norm and self-efficacy as mediating variables, as proposed by the Theory of Planned Behaviour (TPB) or IMBP, and assess possible relationships and their impact on behavioural intention when other variables come into play, e.g. in the association with roleplaying, competence and empathy.

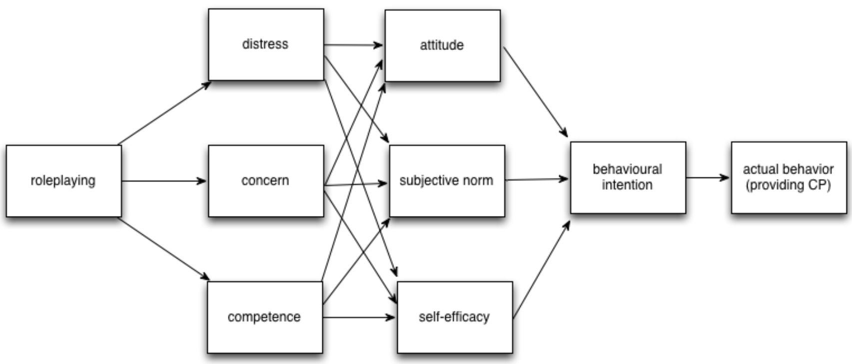

Figure 6.3 Proposed Research Model

By reflecting the Theory of Planned Behaviour (TPB), this study is a first approach. It used TPB-related concepts (attitude, subjective norm and self-efficacy) to assess behavioural outcomes. From the results we deduced a model for further research (see Figure 6.3).

In order to fully make use of the potential social cognition models provide, the concepts and related questions need modification in order to apply appropriate data analysis such as structural equation modelling (SEM). Results from this study will be used to further develop the questionnaire.

It is likely that some of these effects are to be found in other games directed at changing health behaviour designed for other domains or tar-get groups. Besides retrieving information on pupils' behaviour and CPR competence, we were also able to deduce general implications for the use of mobile games for learning from our study. In the light of the experimental setup, a couple of issues arose that need careful consideration for the design of mobile game scenarios. Results indicate that such scenarios have potential to positively impact self-prediction and self-efficacy. The permanent integration of such an application into a school curriculum could help in disseminating the culture of emergency care in the general population, an idea which is corroborated by connatural research (Lubrano et al., 2005).

General Discussion

The research reported in this thesis aimed at further understanding, classifying and evaluating the use of mobile games for learning within educational settings. Starting point were the two main objectives that focused on *identifying structural design elements that make mobile games for learning an engaging experience* and *supporting educational practitioners in effectively choosing and making use of mobile games for learning*. The thesis has approached these objectives in three sequential steps. Based on a theoretical analysis of research in the field it proposed a framework for orientation that helped assessing the educational value of mobile game-based learning offers (**step 1**). It reported the resulting development and evaluation of two exemplary prototypes that were regarded effective and motivating learning scenarios (**step 2**), and presented results from empirical studies that gave further inside as to the pedagogical potential of mobile games for learning (**step 3**). Each study investigated the main objectives from a different perspective. A concluding chapter summarizes and discusses the principal findings from the 3-stage process and deduces implications for educational practitioners. It outlines the limitations of this research and eventually proposes directions for future research in the field.

Main findings

In order to be relevant for educational settings and to truly take advantage of the pedagogical potential ascribed to mobile learning games, it is necessary to make sound statements on their learning outcomes. Thus, in the course of this thesis a framework was created that responded to this need. The thesis started with an extensive literature survey on practical studies, which was presented in **Chapter 1**. By mapping reported outcomes of current research to Game Design Patterns for Mobile Games as defined by Davidsson et al. (2004), the framework unfolded many of the positive effects mobile games for learning can have and pointed to close interactions between the structural elements of mobile game design and educational objectives (Bloom, 1956). The framework was used to (a) assess the influence of mobile game design patterns on learners' motivation to deal with a particular subject and (b) their potential to support the acquisition of knowledge. Further it was employed to identify best practice examples for the implementation of mobile game design patterns that impact learning outcomes.

From the literature review, positive effects with regard to affective and cognitive learning outcomes were identified. With regard to affective learning outcomes it was found that in particular patterns such as *Collaborative Action*, *Augmented Reality*, *Pervasive Games* and *Physical Navigation* had potential to increase learners' motivation to engage with a particular learning environment, i.e. to play the learning game (players were engaged in the game, they exchanged and discussed game progress). It also showed that these patterns fostered students' motivation to engage in learning activities and to deal with a particular learning content (players interacted more with the object of learning, were engaged in discussions, felt "embodied" in the game, were mentally ready for learning and their attitude towards learning material improved). With regard to cognitive learning outcomes, the assumed positive effects were more difficult to substantiate though because only few studies provided empirical evidence for cognitive learning outcomes based on quantitative measurements. However, some of the evaluations reported on positive interrelations between patterns such as *Collaborative Action*, and *Augmented Reality*, *Pervasive Games* and cognitive learning outcomes (players were able to scientifically argument, discussed geometrical aspects of the world, they were able to transfer the learned material and reflected on the process of learning).

In order to better understand the identified design patterns of mobile games for learning, the first literature review was further substantiated. In accordance with its results that emphasized the importance of the patterns *Augmented Reality* and *Pervasive Games*, a second study strongly focused on the educational potential of games that are pervasive and that utilize augmented reality (AR) to enhance the real world with virtual or naturally invisible information for their gameplay. The results were presented in **Chapter 2**. It showed that the relation between context information and learning helped to better understand the effects of individual patterns. From the study it surfaced that both patterns, *Augmented Reality* and *Pervasive Games*, used several context-parameters that diversified their usage and impacted learning. As base for upcoming investigations into the effects of mobile games for learning the linkage between design patterns and learning outcomes, that was abstracted from the two studies, offered a "display case" - like choice of options for the game design concepts and provided examples for their implementation.

In a next step, findings from the literature studies guided the design decisions of two subsequent prototypical developments. Both studies investigated this thesis' main objectives from a different perspective. The study presented in **Chapter 3** approached them from the perspective of a specific target group. It looked at game design that is capable to support motivation in dealing with a given subject (IT-learning) and to enhance cognitive learning outcomes for learners at-risk. The exemplary game development depicted in Chapter 3 responded to this challenge. It illustrated the mobile game environment

WeBuild that was a mobile extension of the Browser Game *BauBoss*. The design process and development of *WeBuild* focused on the integration of learning tasks, the possible tools that supported dealing with those tasks and aspects of the actual game interface. The conceptual phase was informed by a target group analysis that assessed their habits of learning and of using media, as well as their educational needs. The design requirements that were abstracted from the analysis comprised aspects such as motivating provision of and low-threshold access to IT learning content and the need for small chunks of information and diversified activities due to their low attention span.

Based on the identified links between individual game design patterns and learning outcomes, the design of the mobile game environment employed the patterns *Augmented Reality*, *Physical Navigation*, *Collaborative Action* and *Competition*. Learners played the game and it showed that the group of patterns that formed the basis of the application facilitated a game environment, which engaged and motivated learners to deal with IT content and thus had potential to increase cognitive learning outcomes. Pupils liked the concept of the game and had fun walking around outside in teams while using the mobiles, particularly the house building feature and also the chat social interaction and networking.

Chapter 4 focused on better understanding how mobile game environments work in real classrooms and operated by realistic technological and personal support. A design-based research study was reported that chronicled the development of *HeartRun*, a mobile cardiopulmonary resuscitation (CPR) training approach for school children. Addressing school children is regarded one toehold to increase lay helper rates in case of emergency. The conceptual phase was based on an extensive exchange with medical experts in the field, comprising a needs analysis, the refinement of the problem, the characterization of the target group and a review of related work. The design requirements that surfaced implied that a low-threshold, motivating scenario was needed that simulates reality in order to train CPR knowledge.

The design of the mobile game environment responded to these requirements by employing the patterns *Roleplaying*, *Physical Navigation*, *Collaborative Action* and *Augmented Reality*. By using these patterns, *HeartRun* facilitated the simulation of an authentic context where children played an active role in an unexpected emergency involving instant decision-taking on what to do next and the recall of CPR knowledge under time pressure and stress. This way it was expected to enhance psychological preparedness of the rescuer and thus achieving a more prompt and appropriate response. Iterative design circles that involved continous testing with improved functionality resulted in a sound game approach that was used for assessing the potential of the patterns *Role-*

playing, *Physical Navigation*, *Collaborative Action* and *Augmented Reality* in modifying behavioural outcomes and competence. The studies illustrated in Chapter 4 showed how mobile learning games can support students while engaged in an ongoing task in a physical environment. The analysis of qualitative data indicated that the integration of time-critical physical tasks as realized through the pattern *Physical Navigation*, running to the victim and interacting with the manikin by providing CPR, for example, was among the strongest motivational factors and helped pupils to enhance their skills.

A series of subsequent empirical studies further assessed the learning outcomes of patterns or groups of patterns. The first empirical study was described in **Chapter 5**. It looked into an educational setting that coupled a mobile learning game with the PC Browser Game *BauBoss*. The mobile game was realized by way of short messaging services (SMS) that were designed as a quiz. From a pattern point of view this was a realization of the pattern *Coupled Games*. The mobile game application was designed to support at-risk learners with different abilities and capacities. Prior research emphasized the importance of mobile game environments for this target group and evidence was provided for their potential to deliver motivating, low-threshold learning opportunities that enabled the development and improvement of confidence and autonomy, an aspect also frequently associated with using SMS technology for teaching and learning.

The main objective of the research described in Chapter 5 was to understand how *Coupled Games* as one mechanisms of pervasive games can influence information access and motivation for learners at-risk. It was assumed that participants receiving SMS interventions will show higher motivation to deal with IT content in general and software applications in particular than those playing the PC-based version of the game. Also, it was assumed that participants receiving SMS interventions will perform better (higher knowledge gain) than the pupils playing the PC-based version of the game only.

Results provided evidence to support both hypotheses. Participants from the experimental group showed a more positive attitude towards the subject. They accepted the input and dealt with the corresponding IT content, which eventually led to a higher knowledge gain, a valuable aspect with regard to the target group. In addition, as backed by individual statements, the educational intervention triggered social dynamics and collaboration amongst learners, which was a valuable aspect with regard to the target group, too. The use of SMS seemingly caused a change for them and helped them learning.

The second empirical study was described in **Chapter 6**. It further detailed the results on the group of patterns as already presented in Chapter 4. By introducing different roles to the gameplay, the study aimed at assessing behavioral outcomes with regard to attitude, empathy, self-efficacy, and subjective norm. Research in the field has argued that in order to be effective, CPR training should provide for models to produce feelings of personal responsibility and courage required to intervene and to prepare lay helpers emotionally for dealing with unexpected and unwanted situations. Thus, it was proposed that a location-based, collaborative role-playing game, which simulates an emergency situation, can enable this more likely than an information-based learning situation. The review of studies introduced at the outset of this thesis also suggested this. From it, positive effects with regard to this group of patterns in combination with the pattern *Roleplaying* showed. The health related "Virus Game" (Rosenbaum et al., 2006), for example, implemented different roles that interacted with each other. This way, it established social and functional relationships, which engaged learners with the game and led to their feeling "personally embodied" in the game. Further results directed to effects such as identification with the roles in the game (Facer et al., 2004; Costabile et al., 2008), eagerness to work together (Dunleavy et al., 2009) or the feeling of tight association with the tasks in the game (Rosenbaum et al., 2006; Wijers et al., 2010).

Thus, in the context of CPR training, the integration of the pattern *Roleplaying* was assumed to positively impact behavioral aspects, which again were expected to enhance learners' preparedness to help in case of emergency. In order to test this, a series of hypotheses were formulated. Results indicated that the type of scenario significantly influenced self-prediction and that the emotional experience of an emergency simulation as realized by the location-based, collaborative roleplaying game translated to the feeling of self-efficacy. Pupils who participated in the emergency scenario held stronger beliefs that they can provide CPR in case of emergency and they rather predicted that they would do so in case of emergency. Results further revealed a positive relationship between self-prediction and attitude and self-efficacy. The type of scenario did not translate into the other concepts we assessed, though, and results were inconclusive regarding the effectiveness of the type of learning scenario and CPR knowledge. It was assumed that the age of learners had an effect on the outcomes, as well as the place of action because it showed that younger pupils more easily engaged in the simulation, for example. From the age of 15 years onwards it was increasingly difficult for them to engage in the application, especially in public.

Implications for educational practice

From the literature research and the empirical studies that were conducted a collection of design patterns for mobile games emerged that can be linked to specific learning outcomes. Ideally, this linkage supports practical design decisions by enabling educators to chose the most suitable patterns according to their desired learning outcome. The framework could thus strengthen confidence in that the gaming principles selected are relevant for learning.

Yet, interpreting the findings needs careful consideration. Study results from this research indicated that using a particular game can be effective for a specific target group. However, this does not automatically imply that the same game is thus effective for all learners in all learning scenarios. Chapter 4 has provided evidence that using the same simulation game with different target groups has different implications. As depicted in Figure 6.4 the relationship between learning outcomes and game patterns that support mobile learning is indirect and depends on the application context (i.e. aspects related to the target group, learning subject (topic) and learning scenario), which again influence each other. Also, these considerations should be always preceded by the general decision on whether mobile technology is a suitable methodology or if there are other topics, for example, which are better suited for presentation through mobile games for learning.

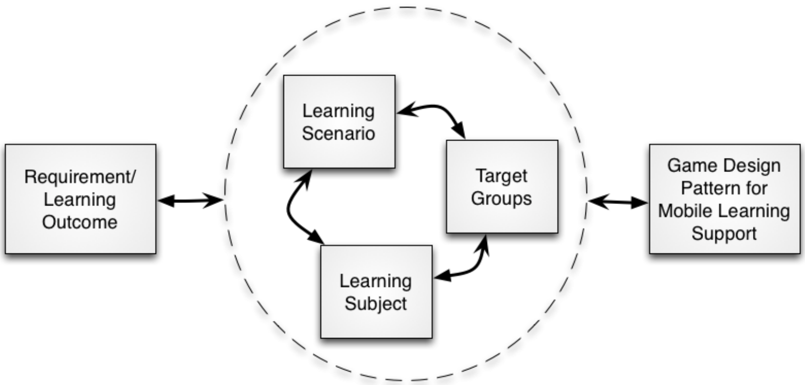

Figure 6.4 Relationship between mobile game design patterns, target group, learning subject, learning scenario and learning outcomes

This relationship is reflected in Table 6.6. It proposes a template as a first exemplary approach towards collecting, describing and documenting game design patterns that have worked within a given context and that were abstracted from this thesis. Thus, the information provided is meaningful for effectively choosing, designing, implementing, distributing and re-using patterns in the sense of structural game design elements. The "problem - context - solution" approach is integrated as "requirement - context - solution".

Table 6.6 Template to describe and document game design patterns for mobile learning support

Category	Description
Requirement/Learning Outcome	Description of the goals learners demonstrate upon completion of a specific mobile learning game. The goals are defined in terms of affective and cognitive learning outcomes, e.g.: *The learner can describe the functioning of components.*
Learning Subject	Domain or discipline of learning that was addressed, e.g.: *Health Education, Natural Sciences*.
Target Groups	Description of the target audience that was addressed, including characteristics such as age, prior experiences with the content, learning styles, motivations, stage within the curriculum or mental characteristics and capabilities.
Learning Scenario	The type of scenario in which the learning took place, e.g.: *Excursions, problem based learning, project-based learning, inquiry-based learning, or blended-learning scenario*.
Game Design Pattern for Mobile Learning Support	Name of the pattern that addressed the required learning outcome.
Pattern Description	Description of the game design pattern to support mobile learning.
Known Pattern Uses/ References	Description of games that have made use of the pattern before and references to the source of the exemplary pattern use in literature.
Exemplary Pattern Implementation	Examples of how the pattern can be implemented within mobile games for learning.
Analysis of Pattern Effects	Results from detailed analysis on the affective and cognitive learning outcomes this pattern can support.
Student Feedback	Feedback from learners who have played a game that made use of the pattern, e.g.: *Learners reported that when they got engaged in the game, they wanted to know more about the history subject inherent in the game as they went along.*
Patterns Frequently Related	List of patterns frequently used in combination with the pattern.

By way of listing learning outcomes that teachers need to focus on and relating them to at least one game design pattern that helps in order to reach the objective, the template aims at providing solutions to educational problems. It puts emphasis on the specific application context of the pattern(s) and gives examples for their realization. The approach is based on the Game Design Patterns for Mobile Games (Davidsson et al., 2004) and describes the learning outcomes according to the taxonomy provided by (Bloom, 1956). Table 6.6 represents the general template scheme. Concrete examples of the filled out template are included in Appendix D. Further research needs to evaluate whether the template fits the needs and expectations of educational practitioners and to assess its value to them.

Playing mobile games in many ways differs from playing games on desktop computers. Regarding their use for learning, this frequently implies leaving exchanging the classroom as a "safe" place for learning and going outdoors to engage with the real world, for example. This implies a frequent shift of attention between different objects, tasks and activities, which can interrupt learning and cause extraneous cognitive load for children. Cognitive overload is an issue instructional design is frequently confronted with and that multimedia instruction is particularly prone to (Mayer and Moreno, 2003). However, the frequent switch between physical and digital worlds as well as diverse objects, tasks and activities is a core design element of mobile games for learning and relates to patterns such as *Augmented Reality* or *Physical Navigation*. Study results showed that the inclusion of physical activity tasks was engaging and enabled participants to enhance their skills, which is consistent with findings from previous research on engagement and learning. However, coordinating tasks such as receiving directions on the device while running through the physical environment needs careful consideration. Setting up the tasks with audio instructions, for example, that direct players through the environment avoided unnecessary switches of visual focus (looking at the device to read subsequent instructions while players are already running to get to the scene of emergency), which was also a safety issue. Also, by interweaving with the "real" physical environment aspects such as self-display while learning come into play. This has been a hitherto neglected aspect of game design for educational games. Environmental aspects need strong consideration for the actual game design though.

With regard to learning game design a series of further implications for educational practice became apparent that need reflection in mobile game design such as the age of learners, for example, that effected the outcomes of mobile learning games. Study results implied that mobile games have potential especially for younger pupils. It showed that up until grade eight, it was comparatively easy to get them involved. However, from the age of 15 years onwards it was increasingly difficult for them to engage in the application, especially in public. Also, the educational background affected results. Although mobile games for learning are often considered support mechanism especially for learners difficult to reach (Douch et al., 2010; Schmitz et al., 2013b; Traxler, 2010), this target group can also be difficult to involve with games.

Last but not least, this research has provided evidence that the actual graphical user interface (GUI) is vital for the acceptance and usage of mobile learning games. Poorly designed games that do not meet the younger generations' expectations with regard to a mobile learning game quickly disenchant them. This all the more needs consideration with specific target groups. Chapter 5 has provided evidence that learners' low frustration tolerance reflects in their low willingness to tolerate prototypical graphical interfaces for example. Though the growing pedagogic and technological sophistication of mobile learning pilots is evident, increased and sustained deployment of mobile learning will depend on the quality of analysis and evaluation of these pilots and trials (Traxler and Dearden, 2005). Involving professional partners who are skilled in game design can largely refute this argument (Johnson et al., 2013). This, on the other hand, implies that creating mobile games for learning is highly interdisciplinary. Experts of creating materials for learning need to productively collaborate with creators of commercial games for entertainment. Their different objectives and approaches need a sound platform for communication that descriptions of design patterns can provide.

Limitations of this research

By identifying and defining game patterns that support mobile learning this thesis has contributed towards a common understanding of pedagogically sound mobile games for learning. However, this research is largely based upon practical research frequently at the stage of prototypes. From this, certain limitations with regard to validity and reliability derive that need to be taken into consideration. Firstly, the claims that were made are based on learning contexts, which were influenced by research and which have individual systemic constraints. Therefore, generalizing our findings needs careful consideration. Barab and Squire (2004) already emphasized that "contexts are never without agency; there are always teachers, administrators, students, and community members creating context and, therefore, local adaptability must be allowed for in the theory" (p. 11).

Secondly, the research in parts used small test audiences (even below n = 10), which makes generalizations difficult. Cross-examining results from various prototypes and studies are a possible pathway to clear this to some extend (Montola, 2011). Also, results can be attributed at least partially to short-term effects of novelty, which frequently leads to bias in an evaluation. Though participants are used to dealing with mobile devices on a day-to-day bases, using the devices for learning was new to them and it is arguable that participants' perception and attitude towards learning and IT content changed. However, it was assumed that the educational studies did not suffer badly from this argument because study one compared a variation within a learning environment that was new to both groups alike and the technology used (SMS messages) was not a thrilling novelty. As for study two, it used the same technology for both groups. Also, other factors that may influence participants' perceptions, such as prior experience with technology, prior background to mobile learning games, personality type, etc. were not considered. Thus, and in order to corroborate effects, large scale and long-term studies are necessary to assess whether effects change during repeated use, different conditions and over time.

Thirdly, and with regard to patterns, the mobile game design mainly focused on *Coupled Games*, *Roleplaying*, *Physical Navigation*, and *Collaborative Action*. Other patterns were not explicitly part of the presented mobile learning games. However, research has argued that game design patterns should not exist alone and that choosing one game design pattern almost automatically requires the presence of other game design patterns. This also showed from the two literature studies. The impact of individual patterns on learning outcomes was sometimes difficult to determine and the games that were reviewed often focused on a set of patterns. Also, technology allowed for several ways of realizing a pattern. Thus, further research is necessary to better attribute learning outcomes to individual patterns or groups of patterns.

With focusing on patterns, this research does not intend to provide a strict one-to-one mapping of patterns to certain learning outcomes. Just as in traditional education, there is no "magic bullet" (Hattie, 2009) in the sense of one for all. Every objective goes together with an individual set of instructional approaches and techniques (Anderson, 2005). Also, educational interventions address individual groups of learners and thus learning methods need to be proved effective over and over again and if necessary, they have to be adjusted. Therefore, this research intends to offer a "display case" -like choice of options, i.e. linking patterns with possible learning outcomes and give examples for their implementation. Still, the results presented allowed to generate design implications for mobile learning games.

Future research

The research reported in the course of this thesis disclosed the shortcomings and emphasized the power that mobile games for learning have when used in educational settings. Empirical results substantiated findings that were abstracted from prior research, which provided evidence for the potential of mobile learning games to strengthen knowledge, skills, and attitudes towards the subject taught. In addition, this research has further disclosed the vast attraction mobile devices provide for todays young learners, which suggests a more common use. The findings fortify their strength to provide motivating and enjoyable environments for teaching and learning. But despite these bolstering facts the growing body of research has achieved, mobile games for learning are sparsely seen within educational settings. Up until now, research in the field is strongly based on pilot studies and scalable or re-producible learning offers "ready-to-use" are barely in existence. Also, theory development in the field has only started to shape and there is relatively little research on digital game-based learning that directly addresses educational practitioners.

The pattern-based approach this thesis offered is a first step towards this direction. By identifying conceptually based relationships between structural game elements and learning outcomes, it seeks to provide a base and orientation for the design decisions educational designers have to take. Identifying further links is vital in order to support the operationalization, the design, the sharing and the re-use of mobile learning game environments. Focusing on game design patterns, additional research is needed that comprehensively evaluates their potential and effects though, in isolation and in combination with other patterns. Future studies need to address the degree of effects, for example the degree of motivational effects of individual patterns, e.g. intrinsic versus extrinsic motivation (Schiefele and Schreyer, 1994), as well as influencing variables such as age or the prevailing level of education (i.e. educationally disadvantaged learners).

In addition, directly linking structural game elements and learning outcomes is a challenging task because this relationship is mostly mediated by target group requirements, choice of topic and learning situation. The interrelationship of the various factors makes theory building difficult and future research needs to investigate how instructional methodologies, game design principles and pedagogies can be phased in order to design meaningful and engaging learning games. As mobile technologies are more and more ubiquitous and influence the younger generation's habits of communicating as well as their daily activities, new issues arise that influence the design of mobile games. Eventually, surprisingly little research on how game elements influence or change behavior is in existence. Pervasive technologies frequently used by mobile game-based learning offers are by no means neutral, interchangeable instruments that just support human needs, but instead they are assumed to actively enable new modes of human behaviour and human learning (Specht, 2009b).

The research conducted in this dissertation aimed at better understanding how concepts work in real classrooms, operated by average teachers and students, supported by realistic technological and personal support. Further testings through large scale trials in real settings and multiple contexts are needed though, which involve a recurrent designing, piloting, testing, adopting and scaling of developments. They are the source for more elaborated concepts and learning offers in the field and lay the ground for sound statements on their effectiveness, which will subsequently promote their widespread adoption within educational contexts. The results from formative and experimental studies reported in this thesis may help supporting this process.

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Appendices

Appendix A

Research articles concerning digital game based learning approaches for first-aid training, Basic Life Support (BLS) and CPR

Developer	Authors	Type of game/ platform	Aim/target group	Result
First Aid Game Aragonese Center for Educational Technologies (CATEDU)	Marchiori et al. (2012)	Educational video game based on a low-cost software simulation with photo-realistic scenarios and simple interactions	Introduces the theory of basic life support (BLS) and the correct performance of BLS procedures; adresses middle and high school students.	Significant increase in theoretical knowledge, although learners who used the video-game learned less than students in the control group.
iCPR	Semeraroa et al. (2011)	iPhone application	Detects the rate of chest compressions performance by using the built-in accelerometer; addresses lay persons and healthcare professionals.	Participants believed that iCPR helped them to achieve the correct chest compression rate and most users found this device easy to use.
iResus	Low et al. (2011)	Interactive mobile application iPhone	Improves the performance of an advanced life support provider in a simulated emergency situation; no specified target group.	Led to increased confidence in making decisions. Participants claimed they would be prepared to use the app in real clinical emergencies. Participants did not think using such an "app would be unprofessional or indicate poor training.

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Table Research articles BLS and CPR – *Continued from previous page*

Developer	Authors	Type of game/platform	Aim/target group	Result
JUST VR System Swiss Federal Office for Education and Science/EU IST JUST project	Ponder et al. (2002)	Interactive scenario where the trainee faces a huge rear-projection screen displaying stereo images of the simulation including a Virtual Assistant	Trains decision-making capabilities under close to real stressful conditions in case of emergency; no specified target group.	First results on usability issues: easy to use system. Navigation and interaction paradigms seem to be intuitive and trainees get used to them quickly. The use of trainee-VA natural speech communication, as expected, is natural and robust.
LISSA	Wattanasoontorn et al. (2014) Wattanasoontorn et al. (2013)	Videogame-based learning environment with 3D realism.	Provides feedback on the performance of specific parameters of the CPR procedure, i.e. chest compression rate and correct arm position. No specified target group.	Led to increased learning outcome when used after manikin based class. Improved learning outcome when reused. Positive perception on learning contexts such as effectiveness, usefulness and ease of learning.
MVW-CPR	Creutzfeldt et al. (2012)	Multiplayer virtual world (MVW) technology with an avatar by use of a high fidelity full-scale medical simulator	Trains first-aid knowledge; addresses medical students	Better knowledge and performance through training with avatars as a method for pre-training, or repetitive training, on CPR-skills.

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Table Research articles BLS and CPR – *Continued from previous page*

Developer	Authors	Type of game/platform	Aim/target group	Result
Quest Atlantis Emergency course	Tüzün (2007)	3D multiuser video game environment with quests as part of the narrative.	Introduces first-aid knowledge; addresses school children	Potential in yielding positive pedagogical changes, e.g. more active learning modes. Students collaborated through discourse and actively engaged in problem-solving and decision-making.
Relive Italian Resuscitation Council (IRC)	Semeraro et al. (2014)	First person 3D adventure	Increases awareness on CPR and prompting to attend CPR classes and be prepared to intervene in case of cardiac arrest; adresses kids and young adults.	No evaluation results available.
Viva! CPR	Semeraro et al. (2014)	Smartphone application	Provides real time feedback on chest compression quality; addresses children and young adults.	No evaluation results available.
Viva!Game Italian Resuscitation Council (IRC)	Semeraro et al. (2014)	Web-based serious game	Creates awareness on cardiac arrest and cardiopulmonary resuscitation (CPR); addresses kids and young adults.	No evaluation results available.

Appendix B

Text messages sent to the experimental group

Date	Time	Kind of sms posted to the experimental group
20.01.201	16:30	Personalized message
23.01.2012	16:10	Text messaging quiz
25.01.2012	09:41	Personalized message/hint on score of friends
27.01.2012	16:01	Information on IT content
30.01.2012	16:00	Text messaging quiz
01.02.2012	08:30	Personalized message/hint on score of friends
03.02.2012	16:00	Information on IT content
06.02.2012	15:30	Text messaging quiz
08.02.2012	12:45	Information on IT content
10.02.2012	10:41	Text messaging quiz
13.02.2012	14:56	Personalized message/hint on score of friends
15.02.2012	15:00	Information on IT content
17.02.2012	12:30	Text messaging quiz
21.02.2012	12:02	Information on IT content
22.02.2012	11:03	Personalized message/hint on score of friends
27.02.2012	11:30	Text messaging quiz
29.02.2012	11:43	Personalized message/hint on score of friends
02.03.2012	14:33	Text messaging quiz
05.03.2012	13:29	Personalized message/hint on score of friends
07.03.2012	11:00	Closing message

Appendix C

Survey questions used to measure the concepts

Concept	Questionnaire items
Self-Prediction	You are in a large shopping mall and you have to go to the toilet. There you find a lifeless stranger lying on the floor. The person is not breathing and is unconscious. If you would find a stranger in this situation, how likely is it that you would use heart massage?
Attitude	Using heart massage by an onlooker on a person lying on the floor without breathing and being unconscious is harmful/beneficial good/bad worthless/useful pleasant (for me)/unpleasant (for me)
Self-efficacy *Capacity beliefs*	How sure are you that you can apply heart massage? I am confident that I will be able to give heart massage. For me applying heart massage in emergencies is easy - difficult
Autonomous beliefs	The decision to apply heart massage is not up to me. Whether I give heart massage or not, that is not up to me.
Subjective Norm	Knowing how to provide CPR, I feel under social pressure to help in case of emergency. I feel responsible to provide CPR in case of emergency.
Empathy	I sometimes feel helpless when I am in the middle of a very emotional situation. In emergencies I feel restless and very uneasy. Mostly I am rather effective while dealing with emergencies. If I am in a tense emotional situation, I am afraid. If I see that someone gets hurt, I normally stay calm. I have the tendency to lose control during emergency situations. If I see that someone is abused, I feel that I have to protect that person a little bit.

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Table Survey questions used to measure the concepts – *Continued from previous page*

Concept	**Questionnaire items**
Distress	When I see someone being treated unfairly, I sometimes don't feel very much pity for them. I often have tender, concerned feelings for people less fortunate than me. I would describe myself as a pretty soft-hearted person. Sometimes I don't feel sorry for other people when they are having problems. Other people's misfortunes do not usually disturb me a great deal. I am often quite touched by things that I see happen. When I see someone who badly needs help in an emergency, I go to pieces.
CPR knowledge	What is the European emergency number? Where must you place your hands when providing Cardio-Pulmonary Resuscitation (CPR)? On the left side of the chest On the right side of the chest At the upper end of the breastbone At the center of the chest People who have a cardiovascular arrest, do not move and show no respiratory movements. yes / no What does this sign stand for? Device that treats arrhythmias with electric shock Emergency telephone with direct contact to rescue services Department in the hospital for people with heart problems Access for people with pacemakers not allowed

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Table Survey questions used to measure the concepts – *Continued from previous page*

Concept	Questionnaire items
CPR Competence	I know where to place my hands on the victim's chest
	I can recognize a person who is in cardiac arrest
	I have the skills to administer chest compressions
	I know when the moment is there to call an ambulance
	I know how to fold my hands for chest compressions
	I know when I have to administer rescue breaths as well
	I have the skills to administer rescue breaths
	I have the skills to use an automated external defibrillator (AED)
	I have the skills to open the victim's airway
	I know how long chest compressions and rescue breaths should be administered
	I know the chest compression rate and when to alternate with rescue breaths
	I know what to do in case the victim's ribs are breaking.

Appendix D

Templates to describe and document game design patterns for mobile learning support - Template i

Category	**Description**
Requirement/Learning Outcome	Pupils appreciate the learning material. They accept the learning offers. They are engaged. Pupils can describe and illustrate a given learning content. They can discuss a given subject and reflect on the process of learning.
Learning Subject	Geometry/Mathematics, History, Health, IT
Target Groups	Learners from secondary education/upper high school from the age of 13 to age 18, university students, learners at-risk from the age of 17 to age 21.
Learning Scenario	Excursion, orientation rally, curriculum related lectures, inquiry-based learning
Game Design Pattern for Mobile Learning Support	*Augmented Reality*
Pattern Description	Players' perception of the game world is created by augmenting their perception of the real world.
Known Pattern Uses/ References	"Mobile Math" / Wijers et al. (2010) "Mobile Game" / Schwabe et al. (2005), "Virus Game" (Outbreak@The Institute) / Rosenbaum et al. (2006), Viking Ghost Hunt" / Carrigy et al. (2010), "WeBuild" / Schmitz et al. (2012b)

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Table Template to describe game design patterns – *Continued from previous page*

Category	Description
Exemplary Pattern Implementation	Simple augmentation by adding virtual objects to places that the target group is in touch with during their daily school experience. Virtually attaching basic information or tasks to physical objects by adding QR codes, e.g. students' handhelds provided them with supporting documents, interviews with on-location experts and witnesses, and virtual samples that they could take at their current location. Objects are virtually placed on the map and have tasks or questions attached to them, e.g. creating geometrical shapes on a previously defined playing field (map), students create an imaginary layer on top of the physical reality. The players' view of the scene is augmented by animations displayed on top of the live video stream in the viewfinder of the camera.
Analysis of Pattern Effects	*Affective Learning Outcomes*: Students feel "personally embodied" in the game. Their actions in the game are intrinsically motivated (Rosenbaum et al., 2006; Klopfer and Squire, 2007). Learners are engaged and motivated to learn and use foreign languages (Connolly et al., 2011). Players immerse themselves in the game (Carrigy et al., 2010). Students are mentally ready for learning (Schwabe et al., 2005). *Cognitive Learning Outcomes*: Students notice and discuss geometrical aspects of the world (Wijers et al., 2010). They can describe and illustrate a disease model (Rosenbaum et al., 2006). Students reflect on the process of learning (Costabile et al., 2008).

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Table Template to describe game design patterns – *Continued from previous page*

Category	Description
Student Feedback	Participants enjoyed the process of physically moving around the environment hunting. Students experienced the threat of disease in the game in an intuitive and visceral way, as though it were real. They felt some attachment to the virtual characters and a sense of responsibility to treat them. Participants demonstrated a strong appreciation of the virtual reconstruction of their group performance (showing the missions solved correctly and any errors on the digital map).
Patterns Frequently Related	*Pervasive Games, Physical Navigation, Collaborative Actions, Roleplaying*

Templates to describe and document game design patterns for mobile learning support - Template ii

Category	Description
Requirement/Learning Outcome	Pupils are engaged. Learners actively participate in the learning offer. They accept the learning material provided.
Learning Subject	Natural Sciences, History, Health, IT
Target Groups	Learners from secondary education from the age of 13 to age 18, university students, learners at-risk from the age of 17 to age 21
Learning Scenario	Excursion, inquiry-based learning, curriculum related lectures
Game Design Pattern for Mobile Learning Support	*Physical Navigation*
Pattern Description	Players are constantly activated mentally and physically and have to move or turn around in the physical world in order to successfully play the game.
Known Pattern Uses/ References	"Savannah" / Facer et al. (2004), "Time Traveler's in the Medieval Ages" (Winkler et al., 2008) "Alien Contact!"/ (Dunleavy et al., 2009) "Explore! - Gaius' Day in Egnathia" (Costabile et al., 2008), "Virus Game" (Outbreak@The Institute) / Rosenbaum et al. (2006), "Viking Ghost Hunt" / Carrigy et al. (2010), "Webuild" (Schmitz et al., 2012b), "HeartRun" / (Schmitz et al., 2014)

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Table Template to describe game design patterns – *Continued from previous page*

Category	Description
Exemplary Pattern Implementation	Players have to go to real places to get the material necessary for building objects. Players have to find places marked in the map and the mobile device and go there, e.g. groups of students have to walk around trying to identify the place the mission refers to. Players have to quickly find orientation and immediately run to relevant location. Players have to move around their school playground or sports field to find digital objects and to complete tasks. They have to collected additional relevant information by walking around and observing the real-world environment. The game is spread out over a large physical area, so simply to visit all the locations and gather enough information they need to split up to some extent.
Analysis of Pattern Effects	*Affective Learning Outcomes*: Students are highly motivated (Dunleavy et al., 2009). Participants are interested and moved (Schwabe et al., 2005). Students' are exited (Facer et al., 2004).
Student Feedback	Students experienced the threat of disease in the game in an intuitive and visceral way, as though it were real. They felt some attachment to the virtual characters and a sense of responsibility to treat them. The ability to move around in groups across a large campus and act physically and spatially (for example, hurrying to leave a room containing a player or virtual character who is sick) may have contributed to the feeling of embodiment. Participants had fun walking around outside in teams while using the mobiles.
Patterns Frequently Related	*Collaborative Actions, Augmented Reality, Roleplaying*

Templates to describe and document game design patterns for mobile learning support - Template iii

Category	Description
Requirement/Learning Outcome	Pupils accept the learning offers. They are engaged. Pupils can describe and illustrate a given learning content. They can discuss a given subject and reflect on the process of learning.
Learning Subject	Natural Sciences/Biology, History, Health, IT
Target Groups	Learners from secondary education aged between 11 and 18 years, university students, learners at-risk aged between 17 and 21 years.
Learning Scenario	Excursion, orientation rally, curriculum related lectures, inquiry-based learning
Game Design Pattern for Mobile Learning Support	*Roleplaying*
Pattern Description	Players have characters with at least somewhat fleshed out personalities. The play is centered on making decisions on how these characters would take actions in staged imaginary situations.
Known Pattern Uses/ References	"Savannah" / Facer et al. (2004), "Alien Contact!"/ (Dunleavy et al., 2009) "Explore! - Gaius' Day in Egnathia" (Costabile et al., 2008), "Virus Game" (Outbreak@The Institute) / Rosenbaum et al. (2006), "Viking Ghost Hunt" / Carrigy et al. (2010), "HeartRun" / (Schmitz et al., 2014)
Exemplary Pattern Implementation	Within the game just as in reality, different roles are involved in case of emergency.

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Table Template to describe game design patterns – *Continued from previous page*

Category	**Description**
Analysis of Pattern Effects	*Affective Learning Outcomes*: Learners are involved in the game. They feel highly engaged and identify with their roles in the game (Facer et al., 2004; Costabile et al., 2008). Students merge with the game (Rosenbaum et al., 2006). Learners are tightly associated with their tasks in the game (Rosenbaum et al., 2006; Wijers et al., 2010). Students take on an identity. They are eager to work together (Dunleavy et al., 2009). Learners felt rewarded and engaged in the game (Carrigy et al., 2010). *Cognitive Learning Outcomes*: Students can give examples for the importance of communication and collaboration (Rosenbaum et al., 2006).
Student Feedback	Students felt some attachment to the virtual characters and a sense of responsibility to treat them. Students felt they were actually experiencing the Savannah, were identifying with their new roles "as lions" and found it highly engaging. The students often talked in the game as if they were directly experiencing the simulation.
Patterns Frequently Related	*Collaborative Actions, Augmented Reality*

Templates to describe and document game design patterns for mobile learning support - Template iv

Category	**Description**
Requirement/Learning Outcome	Pupils are engaged in the learning offer. They join the learning offer and discuss it. Pupils support given forms of behaviour. They predict to help in case of need. Pupils can recognize and recall the knowledge learned. They can describe and explain the knowledge to be learned.
Learning Subject	History, IT, Languages, Health
Target Groups	High School teachers and juniors, middle school students from the age of 11 to age 14, secondary education (13 - 18 years), at-risk learners.
Learning Scenario	Excursion, curriculum related lectures, blended-learning scenario
Game Design Pattern for Mobile Learning Support	Collaborative Actions
Pattern Description	Some goals in mobile multiplayer games that can only be reached through a *Collaborative Action* executed by two or more players. This includes but is not limited to the action of simply being at the same location at the same time.
Known Pattern Uses/ References	"Explore! - Gaius' Day in Egnathia" (Costabile et al., 2008), "HELLO" (Handheld English Language Learning Organization) (Liu and Chu, 2010), "Virus Game" (Outbreak@The Institute) / Rosenbaum et al. (2006), "WeBuild" / Schmitz et al. (2012b), "HeartRun" (Schmitz et al. 2014)

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Table Template to describe game design patterns – *Continued from previous page*

Category	Description
Exemplary Pattern Implementation	Tasks and questions were integrated to motivate collaboration and to bring about commonly achieved results. Students can ask friends to help them building an object, for example (e.g. subscribe as helpers) or to answer a question. The collaborative learning activity was a story relay race, which was designed based upon a collaborative strategy. In the beginning, the students could listen to several sample stories, after which they were asked to edit a story collaboratively.
Analysis of Pattern Effects	*Affective Learning Outcomes*: Students are engaged in the game (Costabile et al., 2008; Dunleavy et al., 2009; Liu and Chu, 2010; Rosenbaum et al., 2006). Students exchange and discuss game progress (Klopfer and Squire, 2007) *Cognitive Learning Outcomes*: Students memorize their knowledge Collaborative (Winkler et al., 2008) Students can explain and rewrite the knowledge learned (Liu and Chu, 2010).
Student Feedback	The collaborative nature of the game was indicated as another winning factor by both groups. Children enjoyed playing together and demonstrated a good team spirit all over the game. Students in the experimental group stated that completing a task collaboratively in a real context encouraged them to accrue more creations than they did in the classroom. Students enjoyed the game because they could complete a common task collaboratively, which was an interesting experience. Students' engagement and identity as a learner is shaped by his or her collaborative participation in communities and groups, as well as the practices and beliefs of these communities.
Patterns Frequently Related	*Cooperation, Team Play, Common Experiences, Roleplaying*

Summary

The core concern of this thesis is the design of mobile games for learning. The conditions and requirements that are vital in order to make mobile games suitable and effective for learning environments are investigated. The base for exploration is the pattern approach as an established form of templates that provide solutions for recurrent problems. Building on this acknowledged form of exchanging and re-using knowledge, patterns for game design are used to classify the many gameplay rules and mechanisms in existence. This research draws upon pattern descriptions to analyze learning game concepts and to abstract possible relationships between gameplay patterns and learning outcomes. The linkages that surface are the starting bases for a series of game design concepts and their implementations are subsequently evaluated with regard to learning outcomes. The findings and resulting knowledge from this research is made accessible by way of implications and recommendations for future design decisions.

Aim

This thesis aims at supporting the use of mobile games for learning as pedagogical tools. The growing influence and ubiquitousness of mobile technologies as well as their acknowledged effectiveness in facilitating learning for varying target groups and topics has confronted educational institutions with growing pressure for adaptation and change. Mobile technology is regarded one foothold to react to this demand and bring sustainable change to the classroom. The interactive nature of mobile media enhances the learning experience by augmenting objects, places and activities thus adding context to objects of learning. Also, digital games have acknowledged motivational power and can effectively support new ways of learning. Thus, the combination of both mobile technologies and digital games seemingly offers strong pedagogical potential. Still, educational practitioners seem to be reluctant in using this technology and those who want to make use of it have to find ways for employing this methodology alongside with traditional methods for teaching and learning. A particular challenge is to find adequate curricular functions in school where the inclusion of these new cultural resources can and should be introduced (Cook et al., 2011) as well as links to specific learning outcomes. This information is scarcely available, especially with regard to mobile games for learning.

Scope

This research intends to provide educational practitioners with guidance. Based on a theoretical analysis of research in the field, it results in the development of practical concepts for employing mobile games in an educational context, which are presented. This work comprises empirical research that assesses the pedagogical potential of mobile learning games and discusses design issues that educe from it - the proposed game design concepts employ patterns such as *Collaborative Actions, Augmented Reality, Pervasive Games, Physical Navigation* and *Roleplaying* as they are frequent design elements for mobile learning games and studies have provided evidence for their effectiveness with regard to educational objectives. Other patterns and pattern combinations may also support these learning outcomes and the patterns under examination possibly support further learning outcomes. However, considering this is beyond the scope of this thesis and is subject to further research.

Practical Studies

The studies conducted in this research intend to further corroborate the stated link between specific game design patterns and individual learning outcomes. The base of operations is the classification framework that matches game design patterns and educational objectives. The subsequent studies are based on this framework. It was elaborated by abstracting game patterns and corresponding outcome descriptions through a literature review on practical studies that revealed a set of patterns frequently used for designing mobile learning games and that had recognizable learning outcomes. In a next step, two design studies follow that exemplary describe the use of the identified patterns for pre-defined educational objectives and from which further design implications are deduced. Concluding, two empirical studies follow that align their design to the prior study outcomes and that assess concrete learning outcomes for diverse target groups and varying subjects.

Findings

The main findings this dissertation adds to research in the field of mobile games for learning are:

- a classification framework that helps assessing the relationship between individual game design patterns and educational objectives in order to support educational game design decisions.
- exemplary game designs that represent the implementation of specific patterns for mobile game design as derived from the literature analysis.

- results from design studies that highlight design issues, which need consideration when implementing mobile game design patterns.
- empirical results from real settings that provide evidence for the effectiveness of patterns or groups of patterns with regard to affective, cognitive and behavioral outcomes.
- a collocation of design implications with regard to individual patterns comprising *Physical Navigation, Collaborative Actions, Roleplaying* and *Augmented Reality*.
- a first approach towards a common understanding of pedagogically sound mobile games for learning by proposing an exemplary template to collect and present relevant knowledge.

Implications for practice

By identifying and defining exemplary game patterns that support mobile learning, this thesis has contributed towards a common understanding of pedagogically sound mobile games for learning. With regard to learning game design two further aspects became apparent. Poorly designed games that do not meet the younger generations' expectations with regard to a mobile learning game quickly disenchant them. Involving professional partners who are skilled in game design can help to largely refute this situation (Johnson et al., 2013). Future research and game development needs to address the importance of the graphical user interface on motivational and learning aspects. This, on the other hand, implies that creating mobile games for learning is highly interdisciplinary. Experts of creating materials for learning need to productively collaborate with creators of commercial games for entertainment. Their different objectives and approaches need a sound platform for communication that descriptions of design patterns can provide.

Future research

Future research needs to corroborate findings from this research. The studies presented in the course of this thesis shed light on the framing conditions and complexities inherent to learning with mobile game technology. Further game analysis is necessary in order to identify other patterns and corresponding learning outcomes to provide a broad spectrum of patterns to choose from. The resulting concepts and developments need to be tested against the background of predefined learning outcomes, specific learning subjects and diverse groups of learners. This, to provide a sound conceptual base for mobile game design decisions. A general adoption of mobile games with educational practices can only be expected, if this process is successful and the first hints towards the educational value of mobile games can be substantiated.

Samenvatting

Het hoofdonderwerp van dit proefschrift is het ontwerpen van mobiele games voor het leren. De voorwaarden en eisen, die van vitaal belang zijn om mobiele games geschikt en effectief te maken voor leeromgevingen, worden onderzocht. Het uitgangspunt van de verkenning is de benadering door middel van patronen als een gevestigde vorm van sjablonen, die oplossingen bieden voor terugkerende problemen. Voortbouwend op deze erkende vorm van het uitwisselen en hergebruik van kennis, worden patronen voor het ontwikkelen van games gebruikt om de vele regels en mechanismen voor het spelen van games die er bestaan, te ordenen. Dit onderzoek is gebaseerd op patroonbeschrijvingen om leerconcepten voor games te analyseren en op het abstraheren van mogelijke verbanden tussen patronen voor het spelen van games en leerresultaten. De verbanden die hierdoor zichtbaar worden zijn het uitgangspunt voor een reeks concepten voor het ontwerpen van games. Hun implementaties met betrekking tot de leerresultaten zijn achteraf geÎvalueerd. De bevindingen en de uit dit onderzoek voortvloeiende kennis worden toegankelijk gemaakt door middel van implicaties en aanbevelingen voor toekomstige ontwerpbeslissingen.

Doel

Dit proefschrift richt zich op het ondersteunen van het gebruik van mobiele games voor het leren als pedagogische tools. De groeiende invloed en de alomtegenwoordigheid van mobiele technologieÎn, alsmede hun erkende doeltreffendheid bij het vergemakkelijken van leren voor verschillende doelgroepen en onderwerpen, heeft onderwijsinstellingen geconfronteerd met de toenemende druk om zich aan te passen en om te veranderen. Mobiele technologie wordt beschouwd als een houvast om te reageren op deze kwestie en om duurzame verandering in de klas te brengen. De interactieve aard van mobiele media verbetert de leerervaring door de toename van objecten, plaatsen en activiteiten en voegt zodoende context toe aan leerobjecten. Ook wordt aan digitale games motiverende kracht toegeschreven en kunnen zij effectief nieuwe manieren van leren ondersteunen. Zo biedt de combinatie van mobiele technologie en digitale games ogenschijnlijk een sterk pedagogisch potentieel. Toch lijkt er in het praktijkonderwijs een terughoudendheid te zijn bij het gebruik van deze technologie en degenen die er gebruik van willen maken, moeten manieren vinden om deze methodiek samen met de traditionele onderwijs- en leermethoden te gebruiken. Een bijzondere uitdaging is het om voldoende curriculaire functies op school te vinden waar de toepassing van deze nieuwe culturele bronnen, alsook koppelingen naar specifieke leerresultaten kunnen en zouden moeten worden geintroduceerd (Cook et al., 2011). Deze informatie is nauwelijks beschikbaar, vooral als het gaat om mobiele games voor het leren.

Scope

De bedoeling van dit onderzoek is om mensen in de onderwijspraktijk te begeleiden. Gebaseerd op een theoretische analyse van veldonderzoek, zijn de ontwikkeling van praktische concepten voor het gebruik van mobiele games in een onderwijskundige context, die gepresenteerd worden, het resultaat. Dit proefschrift omvat empirisch onderzoek dat de pedagogische mogelijkheden beoordeelt van leerconcepten voor mobiele games en bespreekt ontwerpkwesties die daaruit voortkomen. Uit de voorgestelde ontwerpconcepten voor games komen patronen voort, zoals *Collaborative Actions, Augmented Reality, Pervasive Games, Physical Navigatie* en *Roleplaying* omdat dit regelmatig voorkomende ontwerpelementen voor leerconcepten van mobiele games zijn en studies hebben het bewijs geleverd voor de effectiviteit ervan met betrekking tot onderwijskundige doelstellingen. Andere patronen en patrooncombinaties kunnen deze leerresultaten ook ondersteunen en de patronen die onderzocht worden, kunnen wellicht verdere leerresultaten ondersteunen. Echter, dit valt buiten het kader van dit proefschrift en dient nader onderzocht te worden.

Praktijkstudies

Het is de bedoeling dat de studies die binnen dit onderzoek zijn uitgevoerd de genoemde koppeling tussen specifieke ontwerppatronen voor games en de individuele leerresultaten bevestigd. De grondslag voor de activiteiten is het classificatieraamwerk dat ontwerppatronen voor games en onderwijskundige doelstellingen aan elkaar koppelt. De daaropvolgende onderzoeken zijn gebaseerd op dit raamwerk. Het raamwerk werd uitgewerkt door het abstraheren van patronen voor games en bijbehorende resultaatbeschrijvingen door middel van een literatuurstudie over praktijkstudies, die een set van patronen aan het licht bracht, die vaak gebruikt werden voor het ontwerpen van mobiele games voor het leren. Deze set bevatte herkenbare leerresultaten. Na het raamwerk volgen twee ontwerpstudies die het gebruik van de geÔdentificeerde patronen beschrijven als voorbeeld voor voorgedefinieerde onderwijsdoelstellingen en waarvan verdere ontwerpimplicaties worden afgeleid volgen. Daarna volgen twee empirische studies die hun ontwerp in overeenstemming brengen met de studieresultaten en die concrete leerresultaten beoordelen voor diverse doelgroepen en over uiteenlopende onderwerpen.

Bevindingen

De belangrijkste bevindingen uit dit proefschrift die bijdragen aan onderzoek op het gebied van mobiele games voor het leren zijn:

- een classificatieraamwerk dat helpt bij het beoordelen van de relatie tussen individuele ontwerppatronen voor games en onderwijskundige doelstellingen ter ondersteuning van ontwerpbeslissingen voor onderwijskundige games.
- voorbeeldontwerpen voor games, die de implementatie van specifieke patronen voor het ontwerpen van mobiele games vertegenwoordigen, zoals die zijn afgeleid van de literatuuranalyse.
- resultaten van ontwerpstudies die ontwerpissues benadrukken en waarmee rekening moet worden gehouden bij de implementatie van ontwerppatronen voor mobiele games.
- empirische resultaten vanuit bestaande contexten die het bewijs leveren voor de effectiviteit van patronen of groepen patronen met betrekking tot affectieve, cognitieve en gedragsmatige uitkomsten.
- het gezamenlijk gebruik van ontwerpimplicaties met betrekking tot individuele patronen, waaronder Physical Navigation, Collaborative Actions, Roleplaying en Augmented Reality.
- een eerste benadering richting een gemeenschappelijk begrip over pedagogisch verantwoorde mobiele games voor het leren door een voorbeeldsjabloon voor het verzamelen en aanbieden van relevante kennis te opperen.

Implicaties voor de praktijk

Door het identificeren en definiÎren van voorbeeldpatronen voor games die mobiel leren ondersteunen, heeft dit proefschrift bijgedragen aan een gemeenschappelijk begrip over pedagogisch juiste mobiele games voor het leren. Met betrekking tot het ontwerp van games voor het leren worden nog twee aspecten duidelijk. Slecht ontworpen games die niet voldoen aan de verwachtingen van de jongere generatie met betrekking tot een mobiele game voor het leren, zorgen voor ontgoocheling. Het inschakelen van professionele partners die geschoold zijn in het ontwerpen van games kan helpen om dit argument weerleggen (Johnson et al., 2013). Toekomstig onderzoek en de ontwikkeling van games moeten zich richten op het belang dat de grafische gebruikersinterface heeft op motiverende aspecten en leeraspecten. Dit houdt anderzijds in dat het maken van mobiele games voor het leren sterk interdisciplinair is. Experts die onderwijsmaterialen vervaardigen, moeten productief samenwerken met vervaardigers van commerciÎle entertainmentgames. Voor de verschillende doelstellingen en benaderingen is een verantwoord platform om te communiceren nodig, dat door de beschrijvingen van ontwerppatronen geboden kan worden.

Toekomstig onderzoek

Toekomstig onderzoek moet bevindingen uit dit onderzoek bevestigen. De studies die in dit proefschrift gepresenteerd zijn, werpen een licht op de bijkomende omstandigheden en de complexiteit die inherent zijn aan het leren met mobiele game-technologie. Verdere analyse van games is noodzakelijk om andere patronen en bijbehorende leerresultaten te identificeren om een breed spectrum van patronen te kunnen verschaffen waaruit een keuze kan worden gemaakt. De concepten en ontwikkelingen die daaruit resulteren, moeten vervolgens worden onderzocht tegen de achtergrond van vooraf gedefinieerde leerresultaten, specifieke leeronderwerpen en diverse groepen van leerlingen. Dit om een goede conceptuele basis te bieden voor ontwerpbeslissingen over mobiele games. Een algemene acceptatie van mobiele games met onderwijskundige toepassingen kan enkel worden verwacht als het bovenstaande proces succesvol is en de eerste aanwijzingen van de onderwijskundige waarde van mobiele games kunnen worden onderbouwd.

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New network models for the analysis of disease interaction
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Space Efficient Indexes for the Big Data Era
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Studies in Learning Monotone Models from Data

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Pattern Mining in Data Streams

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Minimal Mobile Human Computer Interaction
Promotor: Prof. dr. L. Hardman (CWI/UVA)

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Distributed Deep Web Search

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User Modeling and Personalization in the Microblogging Sphere

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Networking For Learning; The role of Networking in a Lifelong Learner's Professional Development

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Blueprint Model and Language for Engineering Cloud Applications

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Resource-Aware Business Process Management: Analysis and Support

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Listening Heads

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When Complexity becomes Interesting: An Inquiry into the Information eXperience

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Inference-based Framework Managing Data Provenance

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Architectural Support for Dynamic Homecare Service Provisioning

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Virtual Agents for Human Communication - Emotion Regulation and Involvement-Distance Trade-Offs in Embodied Conversational Agents and Robots

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Variational Algorithms for Bayesian Inference in Latent Gaussian Models

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Understanding and supporting information seeking tasks in multiple sources

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Solving difficult game positions

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Monte-Carlo Tree Search

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Integrative modeling of emotions in virtual agents

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From Scenarios to components

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Correctness of services and their composition

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Paving the Way for Lifelong Learning; Facilitating competence development through a learning path specification

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